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A PRICING POLICY FRAMEWORK FOR PUBLIC TRANSPORTATION FACILITIES

Report 15

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PREFACE

This paper forms part of a research project into transportation pricing policies in Canada undertaken by the Economics Branch of the Canadian Transport Commission. This paper was presented at a seminar on User Charges organized by the Ministry of Transport on May 19, 1972. It was prepared on short notice and therefore it may contain some errors. This paper will be edited and will form part of a future research publication "Rational Road Pricing Policies in Canada" by the Canadian Transport Commission.

PRICING POLICIES FOR TRANSPORTATION PUBLIC FACILITIES

INTRODUCTION AND SUMMARY

The object of this paper is to develop a conceptual framework for pricing transportation public facilities. The analysis in this paper is made in terms of roads; nevertheless the general principles developed are applicable to all modes.

Part I is entitled "A General Statement of Objectives" and an attempt is made to define the objectives of pricing transportation facilities. In view of the national objectives as set out in the National Transportation Act and within the framework of Welfare Economics the general objective of pricing is the efficient allocation of resources. Other objectives of income distribution, national unity, full employment and growth are ignored in this study but this does not mean that the attainment of the objective of efficient allocation of resources necessarily contradicts the latter objectives. The objective of efficient allocation of resources will be satisfied if prices are based on escapable costs.

In Part II the economic characteristics of roads are discussed in terms of public goods, externalities, economies of scale, absolute capital requirements and sunk costs. Additionally, the output unit of road transport and substitutes and complements to roads are discussed. The analysis of this part leads to the conclusion that the road system has most of the economic characteristics of a "natural monopoly" and as

such it should be regulated and controlled by the state but not necessarily financed out of general taxation.

In Part III methods of pricing and financing public transportation facilities are presented. The most efficient pricing mechanism is one which allocates the costs to the users at the time the costs take place (escapability) with minimum cross-subsidization; this may result in a multi-part tariff. In view of high administrative costs this multi-part tariff may be reduced to a simpler price structure.

Part IV evaluates the present price structure on the basis of the criterion of efficiency as analyzed above.

Part V presents "A Specific Statement Of Objectives" in order to present a realistic framework for empirical investigation. It is suggested that pricing be based on an "industrial framework". Administration and other economic costs resulting from changes in the present pricing structure to a new and more efficient one should also be considered. In conclusion, the criterion of the efficient allocation of resources will be met by full recovery of retrievable costs from transportation users, with minimum cross-subsidization among modes and among classes of users within each mode, and with consideration of all economic institutional and constitutional constraints.

CONTENTS

I A GENERAL STATEMENT OF OBJECTIVES

1. Search for objectives - Efficient allocation of resources

The definition of objectives is the most crucial issue in the formulation of transportation pricing policies. Generally there has been a lack of definition of objectives with respect to the pricing policy in Canada in the transportation sector. It appears essential therefore that the objectives of this study be clearly set out prior to any empirical investigation of transportation pricing policies in Canada.

Maximization of social welfare

The object of this study is to formulate an appropriate theoretical framework for road pricing and compute a set of road prices in order to improve the present state of social welfare in Canada. The general objective therefore is the maximization of social welfare and the policy instrument variable is the transportation pricing. In order to attain this objective it would be necessary to formulate a set of criteria for evaluation and comparison of alternative economic states resulting from different sets of prices. i.e. different arrangements of the resources of the economy and of economic activities, resulting from different sets of prices. Admittedly there is a strong input of value judgement in the evaluation and comparison of different economic states and welfare economics attempts to deal with this issue.

The comparison of alternative economic states may be made on the basis of value judgements with respect to income distribution and allocation of resources. The issue of

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evaluation of alternative economic states due to variations in income distributions requires many additional value judgements and therefore it does not belong to the domain of economic analysis. This issue is usually either ignored or the assumption is made that the present and/or resulting income distribution is the "best" one with reference to maximization of social welfare. The economist can deal effectively with the second issue of the allocation of resources and he only needs to make one value judgement; he makes his analysis on the basis of the hypothesis that a reallocation of resources will improve welfare if at least one person is made better off without making anyone worse off. The optimum allocation of resources (Pareto optimum) is attained if it is impossible to reallocate resources without making at least one person worse off.

Efficient Allocation of Resources

The necessary conditions[1] for Pareto optimality are:

a) for all consumers the rates of substitution of each commodity are equal;

b) for all producers the rates of transformation for each factor are equal;

c) the rates of substitution are equal to the rates of transformation.

Labour (leisure) is also considered as a factor of production (consumption good) in the present analysis. This would then imply that the proportionality as stated in (c) above is not

[1] For a detailed account of these conditions and for further analysis on the issue of welfare economics see Henderson and Quandt, Micro Economic Theory, McGraw-Hill Co. (1958).

sufficient condition but for an optima we must also have an equality of price to marginal cost.

The above conditions defines a frontier - the Utility Possibility Frontier. All points lying outside the frontier are unattainable given the society's existing resources. All points on and inside the frontier are attainable. The points on the frontier represent economic states where the allocation of resources is optimal.[2]

It can be shown that the conditions of optimal allocation of resources are met by the perfect competitive market in the absence of economies or diseconomies, hence all economic states of perfect competition lie on the frontier. This is shown in Figure 1. For simplicity it is assumed that the society consists of two individuals A and B. Their level of utility UA and UB is measured on the axis. The perfect competitive market in the absence of economies and diseconomies is an economic state located anywhere on the utility possibility frontier (UPF) ie. points 2, 3 and 4. In this diagram economic state 2 is superior to economic state 1 because the utility level for both individuals is higher in economic state 2, than 1, i.e. both individuals are better off at point 2.

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[2]All frontier points represent maximum efficiency but different income distributions. One of the frontier points may be chosen by the society through the "social welfare function".

The movement from point 1 to point 3 does not meet the Pareto optimal conditions; individual A has a higher level of utility i.e. he is better off at point 3 than at point 1 but individual B has a lower level of utility i.e. he is worse off at point 3 than point 1. Point 4 lies directly above point 1 and is "better" than point 1 on the basis of Pareto optimality because individual A is better off where individual B has the same level of utility in both points. Economic state 5 lies outside the frontier and it is unobtainable given the existing resources of the society.

Constraints

The real world is far from a perfect competitive one. It consists of imperfect markets, uncertainty, discontinuities, economies and diseconomies. It is a world where the outcome of economic policies is not easily predictable. The economic state of the real world lies inside the production possibility frontier i.e. point 1 in Fig. 2 and only by remote accident would lie on it. On the basis of Pareto optimality social welfare can only improve by a movement from economic state 1 to anywhere in the shaded portion of the diagram. Any economic policy therefore that will produce a movement from point 1 to any other point in the shaded portion of the diagram is considered to be an optimum policy. This movement of course is limited again by the frontier due to the limited social resources. Any economic policy that will produce a movement from point 1 to any other point in the shaded portion of the diagram is considered to be an optimum policy. This movement of course is limited again by the

frontier due to the limited social resources. Any economic policy that will produce a movement to point 7 will decrease welfare and therefore it is an inferior policy. We cannot evaluate any economic policy that results to a movement from 1 to 6. We can only say that this policy does not produce a Pareto optimal economic state.

So far in this analysis it has been suggested that the road pricing policies should be based on the criteria of Pareto optimality ignoring all distributional considerations. As a first step, the present pricing structure of the road system will be analyzed on the basis of Pareto optimality. If found unsatisfactory then a new set of road prices will be formulated on the basis of the criteria of Pareto optimality; but this criterian may call for different policies depending on whether the economy is in a state of full employment and steady growth or not. In this paper the intention is to limit the approach to the first alternative by assuming full employment and steady growth. It may also happen that the spirit of nationalism and militarism of the Canadian people may demand more national unity and more national defence through bigger, better and more costly road systems. These are also valid goals but they are ignored in this analysis. This is not to say of course that an economic policy to increase optimality of the road system will necessarily contradict some of the latter objectives. We do not know if the above limitations constitute a serious defect

in our analysis. In the present context the economic state of Canada may be depicted by point 1 in Figure 3. The road system contributes $\sim$ 3% to the Canadian GNP. This percentage gives an indication of the maximum effect that any change in the price structure of the roads may have in the social welfare of Canada. This maximum effect is shown in Figure 3 by a small circle around the point 1. "Good" economic policies will produce a movement from point 1 to the shaded part of the circle preferably on the periphery such as point b; "bad" economic policies will produce a movement towards point "a" and in the same quadrant as point "a".

"Theory of Second Best"

Is it possible that we might ensure the above optimal movement by producing a new set of road prices in Canada? At first this possibility was ruled out by Mead, and Lipsey and Lancaster in their Theory of Second Best*. According to this theorem any economic state where a number of Pareto optimum conditions are met, but not all, is not necessarily "better" than any other state where a lesser number of Pareto optimum conditions are met. Therefore, if the Pareto optimum conditions are met in the pricing of the roads it will not necessarily imply an improvement in the allocation of resources in the whole economy. This is a rather pessimistic view and limits drastically the power of economic policy.

Further developments in economic theory have modified substantially the above conclusions. According to these developments, optimal conditions can be based on the degree

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*R.G. Lipsey, K. Lancaster, "The General Theory of Second Best", Review of Economic Studies, Vol. 24 (I), No.63.

FIG. 1

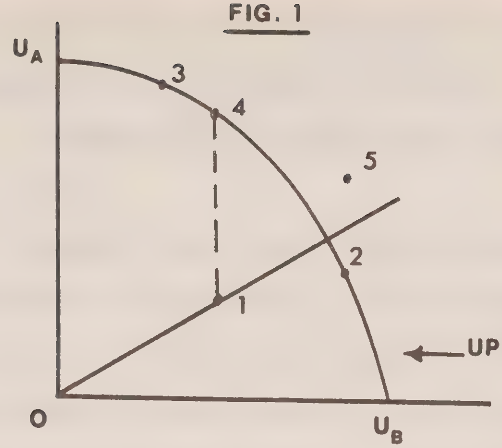


FIG. 2

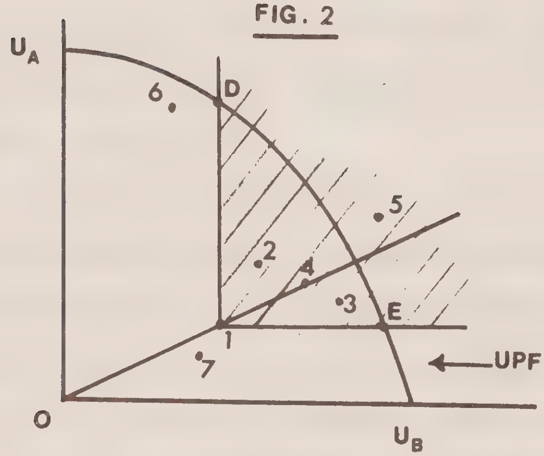
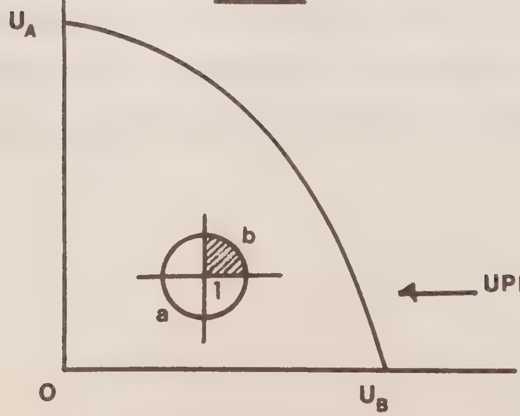


FIG. 3



of substitutability or complementarity of the commodity in question, i.e. roads, in relation to all other economic goods. A simplified example might help the analysis at this point.

Assume a good "topi" has neither substitutes nor compliments in the rest of the economy; then the market for "topi" is completely separate from the markets for all other goods. Effectively we have two markets one for "topi" and the other for all other goods. It is self-evident that given the community's resources and the pricing structure of all the other economic goods the social welfare will increase if "topi" meets the Pareto conditions by marginal cost pricing.

Road versus Road Transport and other modes

It may not be realistic to assume that the roads have the same economic characteristics as "topi" in terms of substitutability or complementarity. The road transport consists jointly of road end vehicles. This implies a strong complementarity between roads and vehicles. There are also strong substitutes, to road transport, i.e. rail, marine, air and pipeline modes of transport. All these modes lumped together form the transport sector of the economy. At this point it may not be totally unrealistic to assume that transport is neither a strong complement nor a strong substitute to the rest of the economic

sectors.[3] (This assumption may be easily reversed depending on the way we define the output of the economy. For the purposes of this analysis this assumption is considered valid.) It follows, therefore, that any new set of prices in transport which will produce a Pareto optimum in transport will also increase the level of social welfare as a whole. It is suggested here that the optimality of transport could be analyzed independently from the rest of the economy.

The above analysis applies to transport as a whole but not necessarily to each transportation mode. There is a strong degree of substitutability between road transport and the other modes. In view of the existence of substitutes for road transport optimality may be achieved by an optimal pricing for road transport; the ratio of this optimal price to marginal cost for road transport should lie in between the ratio of price to marginal cost of all other transport modes. If marginal cost pricing is the rule for all other modes then the same rule would apply to road transport. If all other modes are subsidized then the roads should also be subsidized by an "equivalent" amount and its optimal price

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[3]This assumption is sufficient for the following discussion but not a necessary one. Instead the following approach may be taken. If there are two goods or two groups of goods in the economy, the efficient allocation of resources will improve if they are priced at the cost of production. If one of the two is priced optimally, and no hoarding is allowed, then this will necessarily result in the other one being priced optimally as well. If we now extend this to transportation it may be assumed that the two goods are the transport sector versus the rest of the economy. If the transportation is priced to cover its costs of production then the rest of the economy will as well, as a group. This will be a first step in optimization of resources. By bringing, therefore, all other economic sectors together and optimize transportation we can assume that it will lead to an improvement in the allocation of resources.

would be lower than its marginal cost. So much for the pricing of road transport.

The issue in this paper is the pricing of roads which in conjunction with the vehicles provides road transport. Due to the strong complementarity of the road and the vehicle the optimum pricing of roads will depend on the pricing of the vehicles. Following a similar analysis as above if the vehicle is priced above its marginal cost then the road optimal price would be below its marginal cost. If the vehicle is subsidized its price being below its marginal cost then the road optimal price would lie above its marginal cost.

It is evident therefore that in order to proceed with the pricing of roads it is required that additional assumptions about the pricing of the other transport modes and the vehicles are made:

(a) the pricing of all the other transport modes meets the Pareto optimal conditions;

(b) the pricing of the vehicles meets the Pareto optimal conditions.

Therefore any set of prices for roads that meet the criteria of Pareto optimum will also improve the allocation of resources in the economy and increase the social welfare.

How realistic are these above assumptions? It would be worthwhile to investigate this question which may be answered on the basis of the present pricing structure and

also in the light of the Canadian objectives for economic policies in transport in general.

With respect to the vehicle pricing it is more likely that a vehicle manufacturing industry follows a mark-up method of pricing rather than pricing on the basis of marginal costs. At this stage it can be stated that a mark-up method of pricing does not necessarily contradict a method of pricing on the basis of long-run marginal costs. We are prepared therefore to assume for the purpose of this analysis that the automotive industry has a pricing structure that meets the Pareto optimum conditions.

It is more difficult to make any statements about the degree of optimality of each of the other transport modes. Most of the transport modes today are likely subsidized by different levels of government. The degree of subsidy has not been estimated yet; the method of subsidy is not uniform among the different modes and the approach taken so far in pricing transportation in general is not comprehensive but produces a non-optimal structure and misallocation of resources as a consequence.

Canadian objectives National Transportation Act

Recently the intent to optimize the resources in the transport sector of the economy has been clearly expressed by the federal government. The Royal Commission on Transportation (1961) has strongly recommended the transportation economic policies to follow the criteria of optimum allocation of resources. These objectives of the Royal Commission

on Transportation were embodied in the National Transportation Act (NTA). The NTA was passed in 1967 by the Federal Government and reflected the criterian of optimum allocation of resources. The preamble of the NTA declares that:

"...... an economic, efficient and adequate transportation system making the best use of all available modes of transportation at the lowest total cost is essential to protect the interests of the users of transportation and to maintain the economic well-being and growth of Canada, and that these objectives are most likely to be achieved when all modes of transport are able to complete under conditions ensuring that having due regard to national policy and to legal and constitutional requirements

(a) regulation of all modes of transport will not be of such a nature as to restrict the ability of any mode of transport to compete freely with any other modes of transport;

(b) each mode of transport, so far as practicable, bears a fair proportion of the real costs of the resources, facilities and services provided that mode of transport at public expense;

(c) each mode of transport, so far as practicable, receives compensation for the resources, facilities and services that it is required to provide as an imposed public duty..."

It is strongly suggested, therefore, to apply the criterion of efficient allocation of resources to all modes in the study of road optimum conditions it is assumed that Pareto optimum conditions for all other modes are or will be met, and proceed with the formulation of a set of road prices on the basis of the criterion of efficiency. Consequently these prices will increase the level of social welfare in Canada.

Conclusions

It has been shown that the social welfare of the economy will increase if the conditions of Pareto optimality are met in the pricing of the road system. These conclusions are based on the following assumptions:

(a) the economy is in the path of full employment and steady growth;

(b) distributional considerations are ignored;

(c) additional objectives such as national defence, national unity are also ignored;

(d) Optimal conditions prevail in the pricing of all transport modes with the exception of the road;

(e) Optimal conditions prevail in the pricing of the automotive industry.

2. <u>Efficient Allocation of Resources Through Marginal Cost Pricing</u>

The general objective is to formulate a framework for road pricing and compute a set of road prices which will increase social welfare on the basis of the criterion of the optimum allocation of resources. The question that remains is how to fulfill this criterion. This question is not limited to the roads only but is relevant to most economic goods. Economists argued through long cumbersome and heated debates on the optimality of marginal cost pricing. It is the intent here to apply these ideas in the pricing of the road system.

Marginal cost pricing

Marginal cost pricing is a very useful theoretical tool; its application is enhanced by the economic characteristics of the real market goods, i.e. indivisibilities and excess capacity; marginal cost pricing may redistribute income in favour of the consumers of goods produced in the decreasing cost industries, and may result in over-investment in the decreasing cost industries. Despite its shortcomings marginal cost pricing provides a useful framework for pricing. Instead of abandoning this concept we shall attempt to develop a pricing framework for roads which makes use of the marginal cost pricing system and overcomes some of the problems associated with it.

An important issue that appears in the empirical studies is that associated with the definition of marginal costs. The question, what constitutes marginal cost of the road system should be carefully analyzed. It is not always

obvious to distinguish between fixed costs and marginal costs, "There is no such quantity as the marginal cost of output; there is not even a simple choice between two quantities short and long run costs. There is a large variety of costs to choose from depending mainly on how far ahead you choose to look and the collection of costs itself varies from day to day as current commitments alter".[4] This quotation by Lewis gives some indication of the magnitude of the problem which may be illustrated by the following example.

Principle of Escapability

A road joins two towns; the road is owned and utilized exclusively by a firm that provides bus transport daily at 9 A.M. The economic life of the road is twenty years and that of the bus is ten years. The contract for bus operators is renewed every two years. The firm is faced with some expenditures which are repeated seasonally such as snow removal, grass-mowing and periodic maintenance checking of the bus. The bus operates on a set timetable which may be changed at or before 8 A.M. each day. What is the marginal cost of providing transport? There are various possible answers to this question depending on the timing of the question. If this question is asked at 8:30 in the morning then all costs associated with the maintenance and operation of the bus and the road are fixed with the exception of the costs that are imposed by an additional passenger trip. Once the bus trip has been decided, the only variable costs

[4] W.A. Lewis, Overhead Costs, George Allen & Urwin (1949), p. 12.

which can be escaped are those of providing a trip to an extra passenger; these costs are the seat depreciation caused by the passenger and the extra cost of cleaning his cigarette ashes, and infinitesimal additional amount of fuel consumption as well as damage to the tires and the road bed caused by his weight. All these amounts are very small in comparison with the fixed amounts of the tire and road damage and gasoline consumption. The fixed amounts are not escapable given the decision has been taken for the trip to take place. After the bus leaves the terminal there are not any escapable costs. The magnitude of marginal costs is different if the question is asked prior to 8 o'clock in the morning. During this time the vehicle trip may or may not take place and all costs associated with it can be escaped. The marginal cost therefore providing transportation now, is the cost associated with the bus trip and that includes all passenger costs as well. These costs are the road damage due to the vehicle trip, the damage to the tires, the gasoline consumption and some other costs or part of them such as oil change and general overhaul i.e. all costs associated with the bus mileage or number of trips. If the same question is asked with reference to the winter season then there are additional costs that are variable and may be escaped if transportation is not provided during winter. These costs are associated with snow clearing operations. If the firm decides not to provide transportation during the winter the escapable costs are all the ones previously

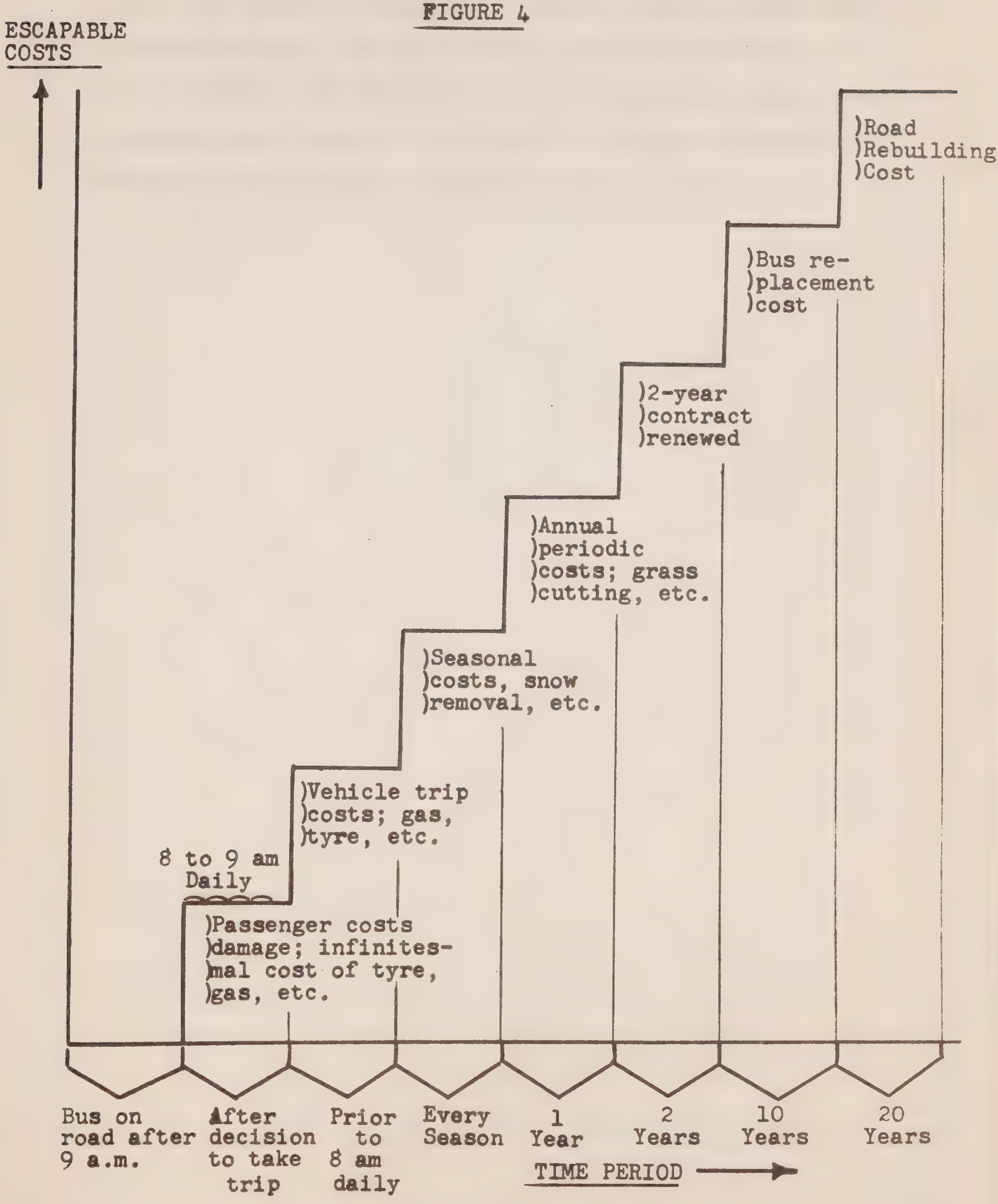
mentioned with the addition of the cost of snow removal. This would also be the marginal cost of providing transportation during the winter season. If the same question is asked at the end of the labour contract with the bus operators which is negotiated every two years then the costs to the transportation firm associated with the wages to the bus operators may be escaped at this time only (it is assumed here that no overtime payments are taking place and no hiring or firing of operators during the contract period). At this time all costs of the transportation firm may be avoided with the exception of the capital cost of the bus and the road. If a decision is taken to discontinue operations at this point the above capital costs can only be considered as fixed costs and they cannot be retrieved. Every ten years the firm is also faced with the decision to invest in a new bus or not. Now, the marginal cost of providing transportation includes the capital cost of the bus. Only every twenty years all costs are escapable since the road needs to be reconstructed. This discussion is illustrated in Figure 4 on the basis of the criterion of escapability of costs.

In view of the above the principle of escapability of costs may provide us with a good framework for the understanding of the vague concept of marginal costs as well as the analysis of road costs in general.

So far the issue of road pricing and its objectives was presented in general if not vague terms. Since the intent of this paper is to make an empirical investigation of

ESCAPABLE COSTS VS. DECISION FREQUENCY

FIGURE 4



the road pricing a great deal more clarity is required. The terms of reference should be drawn with a greater amount of detail reflecting the basic economic objectives of road pricing, the present division of authorities i.e. the political and administrative structure for roads, road transport and transport in general, and the availability of data and the economic characteristics of roads.

II THE ECONOMIC CHARACTERISTICS OF ROADS

Before we proceed with the development of a pricing mechanism, it is necessary that the roads be examined in terms of their economic characteristics.

Definition of Road Users

The beneficiaries of roads may be classified into three general categories: the producers of goods requiring transportation, the transport media, i.e. the vehicle operators, providing transportation, and the consumers of goods that have been transported. Under some restrictive assumptions, the principle of efficient allocation of resources will be satisfied if all road costs are allocated to any or all of these three groups. Within the context of the present Canadian market economy, and since the road has been designed and built with specification of the vehicle rather than to the specific good being transported, the efficient allocation of resources will be satisfied if all road costs are allocated to the transportation media. For purposes of this exercise, therefore, the road user is defined as the owner or operator of the transportation vehicle.[1]

Roads as a Pure Public Goods

The pure public good as defined by Samuelson is one "which all enjoy in common in the sense that each

[1] In the following discussions, the term vehicle may be interchanged with the term vehicle operator or owner.

individual's consumption of such good leads to no subtraction from any other individual's consumption of that good"[2]. This is a widely accepted definition.

Empirical results by Soberman[3] and the "Highway Cost Allocation Study" in U.S.[4] have shown that the road marginal cost of a vehicle journey is significant. The vehicle journey imposes a definite cost to the road system. The damage to the road due to a vehicle journey is a function of the number of axles per vehicle, weight per axle and number of miles per journey.

With reference to the "exclusion principle" our view is that the road utilization is limited to the vehicle owners or operators who are willing to pay some charge for the use of the roads. Only the vehicle owners or operators can make use of the roads and they pay road charges in the form of vehicle licensing or gasoline taxes. Additionally there is some correlation between the size of the vehicle and the cost that it imposes on the road system. The present road pricing mechanism does take this into consideration and as a general rule the bigger vehicles do pay higher charges. Admittedly the exclusion principle may not be applied efficiently because the

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[2]P.A. Samuelson "The Pure Theory of Public Expenditure" a review of economics and statistics, Nov. 1954, pp. 387-389.

[3]Richard M. Soberman "Economic Analysis of Highway Design in Developing Countries" Highway Research Record No. 115, publication 1337, Highway Research Board, Washington, D.C., 1966.

[4]Highway-Cost Allocation Study, Supplementary Report, House Document No. 124, 89th Congress, First Session, Washington, 1965.

marginal cost function for the utilization of roads has not been empirically determined, and because the present pricing mechanism through licensing and fuel taxes may not allow sufficient discrimination among road users. These problems may be difficult to cope with but they are not insurmountable. At a later stage the level of the present road charges as well as the relative distribution of charges among different types of vehicles will be examined and evaluated.

It is the view of this author that the roads are not "pure public goods" for the following reasons:

(a) the roads are not equally available to all; they are available only to the vehicle owners or operators;

(b) the road marginal cost of a vehicle journey is a significant part of the overall cost[5] and

(c) it is believed that the exclusion principle is sufficiently applicable.

Externalities

Transportation is basically a factor of production. Its unique characteristic is that it is a factor of production for nearly all goods. The greater the number of goods that use

[5] In the case of roads (thing being true for most other goods in the economy), there is a trade-off between the road marginal costs of a journey and the construction or capital cost of the road. It is possible that by sinking large funds into the road capital cost to construct a super-strong road which will result in virtually zero marginal costs; this of course would als result in an overall inefficiency.

a specific transport route the smaller the cost of the transport factor of production allocated to each good. These are "pecuniary externalities". Any change in the price of transport will be reflected in the price of the final product. The final beneficiaries of transportation are the consumers of the final products. So far there is nothing unique about transport as the same statements apply to many factors of production.

Any subsidy or overpayment to transportation will distort the efficient allocation of resources. The demand for transport is relatively more inelastic for expensive goods (relative to the volume and weight) because transport would be a small percentage of the total price. Similarly the demand is elastic for inexpensive goods. In the case of transportation subsidies,the final price of the product will not reflect the real cost of the production of these products.

All road transport benefits are associated with the goods transported and are passed on to the consumer who pays a price for all benefits received from the product which he consumes. The transportation externalities are limited to production (pecuniary), as there are no externalities in the "consumption" of transportation as there would be for example, in the "consumption" of education. Therefore, on this basis there is no reason for transportation to be publicly financed.

This brings us to externalities resulting from

benefits, such as land value increases which are alleged to be the sole result of road transport. Land values will increase because of the productive opportunities in the area nearby. Good road transport will facilitate the exploitation of these productive opportunities. The following example may clarify this issue. Suppose a 10-mile road is built in the middle of the "Sahara Desert" (far away from any oasis), no one would seriously expect the land value near this road to increase in value. If a road is now built to a potential mining area the picture changes drastically. The mine could not have been exploited before, because transportation (which is the factor of production of the mining product to the manufacturing centre) could only be provided by air and at great cost. The new road brings the cost of production down to the level where the product could compete effectively. (Other potential mines nearby, even less efficient, may start operating by using this route near the mine above). As mining activity increases, traffic on the road increases resulting in other activities such as restaurants, and gasoline stations along its routes. The demand for land near the route increases and as a result its value goes up. If there are any other productive opportunities along the route they may profit as well. The farmers near the new route may find that the price of one of their factors of production has dropped to their advantage. As a result, the value of their land will increase. This increase in

value is equal to the capitalized value of the benefits they receive due to the new route. These benefits are reflected by the decrease in their transportation costs. If the new road, by their farms is between the mine and the manufacturing centre, but does not lead to market for farm products, no change in farmland values may take place. The causality is of importance here; from productive opportunities to transport to land increases. Again, road transport has a significant effect on an area with productive opportunities only if the good produced is inexpensive relative to its size and weight. If the goods produced are diamonds, air lift may be used. The demand for transport for this commodity is unelastic because of its small percentage of the total value of the product (provided you do need elaborate and heavy facilities). The "ghost towns" are evidence that the increase in land value is not due to roads but due to the existence of productive opportunities. Once the mine is inoperative the land value drops drastically even though no change in the amount of roads provided took place.

In conclusion the roads provide only one kind of externality, the pecuniary one i.e. the greater the number of users of the road facility the less the cost allocated to each one.

At the risk of being repetitive, some of the above points should be restated. The road is not the primary cause or factor of the increasing land values but it is

related to it. The change in land values reflect the change in the prices of the final products transported over the road. The change in the price of the products reflects the change in the cost of one of the facts of production such as the roads. It does not follow that any increase in land values should be allocated to the road, instead it might be more appropriate to allocate any increases in land values to the primary cause or factor of this change which is the productive opportunity i.e. a mine at the other end of the road. In more general terms, this increasee in land values should be associated or allocated to the national product. The implication of all this is that any taxation of land value increases should not be allocated to the road system, instead it should be allocated to the GNP in general and should be called a general tax.

Economies of Scale, Absolute Capital Requirements and Sunk Costs.

The road has economies of scale associated with the type of surface and the number of lanes. At high traffic vaolumes, it is more efficient to have a paved rather than an earth or a gravel road. This is indicated in the Figure 5; for traffic volume less than q_1' it is more efficient to have an earth road. For traffic volume between q_1' and q_2' the gravel road is the most efficient, and for any traffic volume beyond q_2', the paved road is the most efficient. The minimum efficiency points for earth, gravel and paved roads are q_1, q_2 and q_3. Similarly for

high traffic volumes, it is more efficient to have multi-lane roads rather than separate single roads with the same number of lanes. This is indicated in Figure 6.

The unit cost is an important variable in the efficient allocation of resources. Due to the high fixed costs in roads, the average cost function has the shape shown in Figure 7. After the road is built it takes some time before it reaches its design volume, therefore, in the initial stages the demand is at D D. Eventually it shifts to the right at D'D' and reaches even beyond it to D"D". If the government follows a policy of covering the cost, then at the output q_3 it will charge price equal to C_1.

If now a second road is built then the demand for each road will be half of D'D', and it will shift to D D. The unit cost would then be C_1. It is obvious that at this point the second road is a waste of resources. The second road is justified only when the growth of demand crosses the average cost function at $q_4 = 2 \times q_3$. If q_4 was the initial design level for the road, then another kind of road would probably have been designed whose minimum efficient point would be at or close to q_4 and which would have a unit cost lower than the one resulting from the roads shown here.

FIG. 5

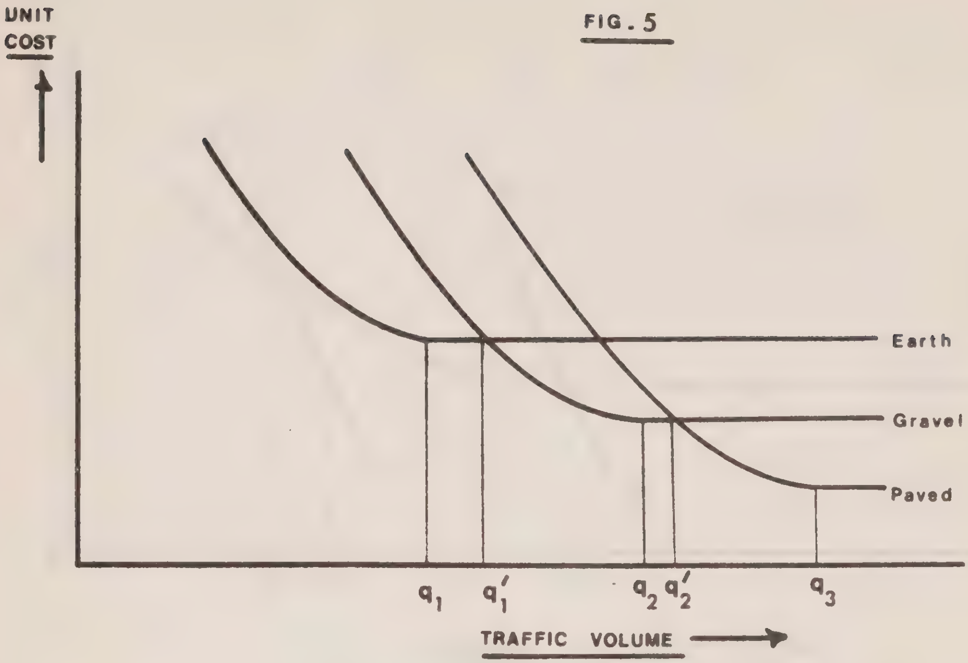

UNIT
COST
Earth
Gravel
Paved
q_1
q_1'
q_2
q_2'
q_3
TRAFFIC VOLUME

FIG. 6

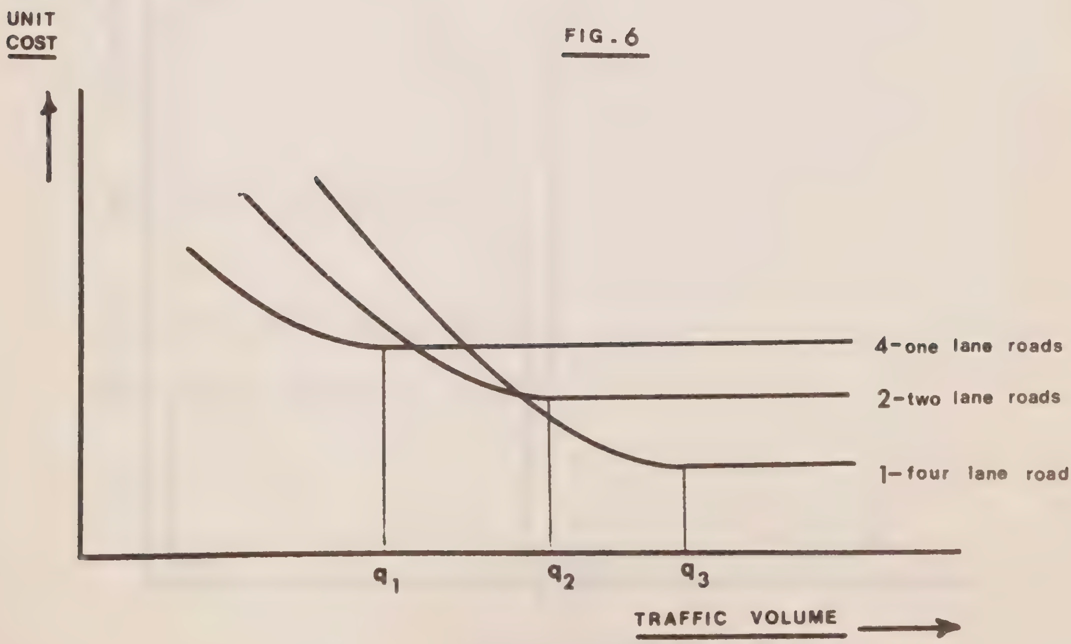

UNIT
COST
4-one lane roads
2-two lane roads
1-four lane road
q_1
q_2
q_3
TRAFFIC VOLUME

FIG. 7

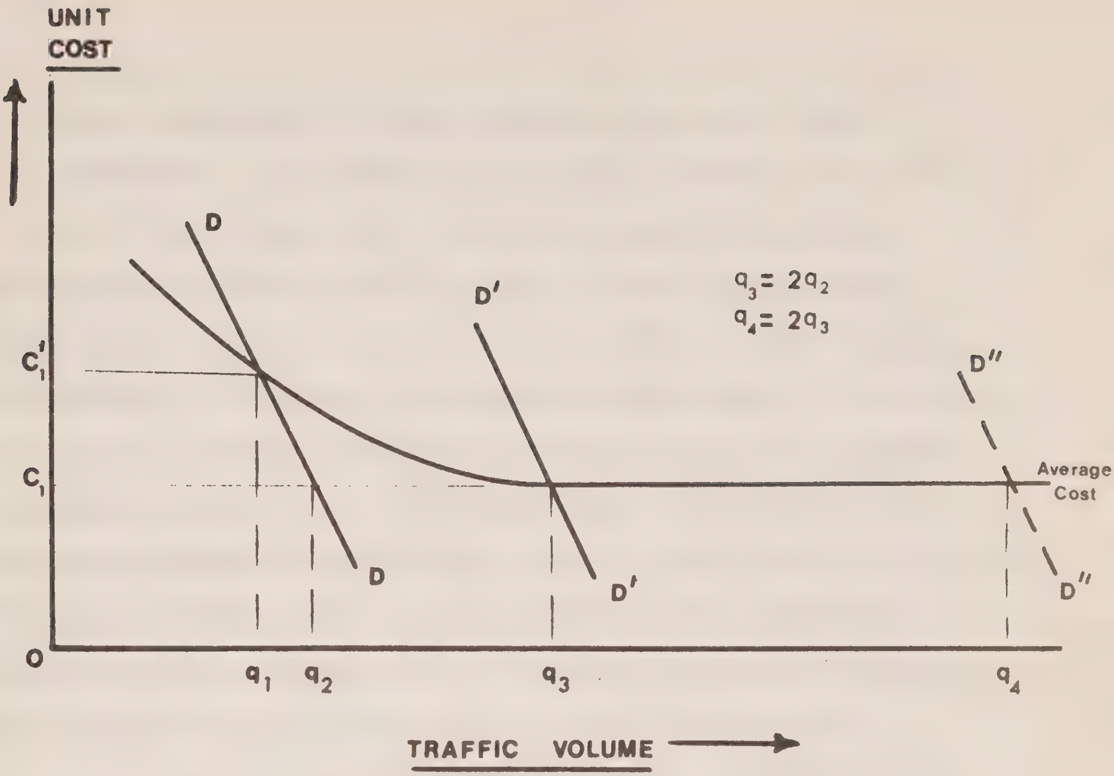
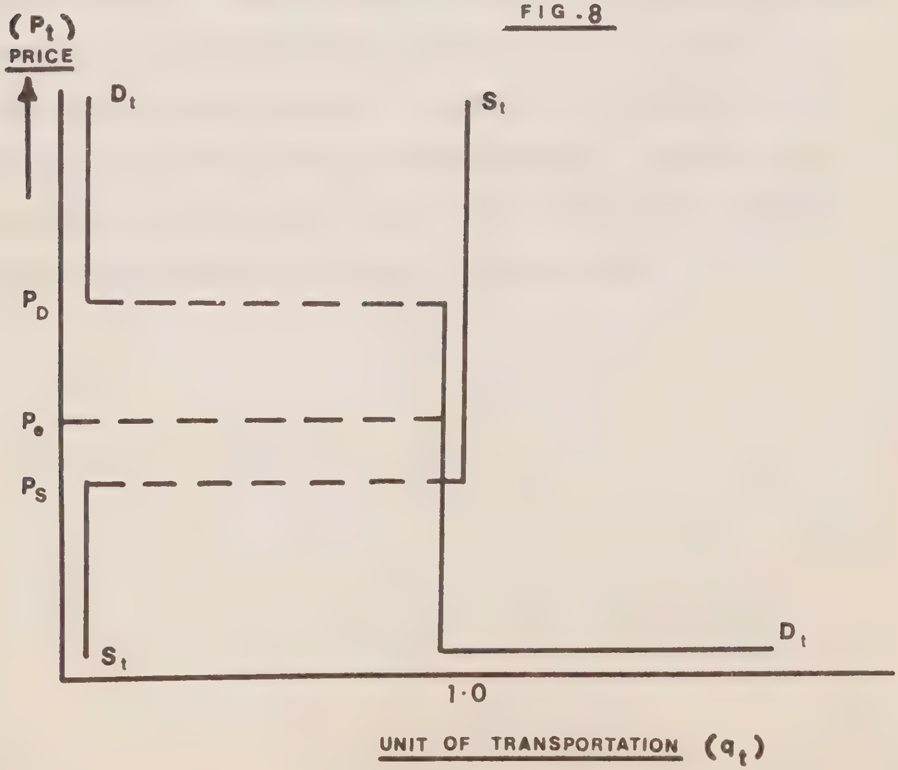

UNIT
COST
D
D
D'
D'
$q_3 = 2q_2$
$q_4 = 2q_3$
D''
D''
C_1'
C_1
Average
Cost
O
q_1
q_2
q_3
q_4
TRAFFIC VOLUME

FIG. 8


(P_t)
PRICE
D_t
S_t
P_D
P_e
P_S
S_t
D_t
1·0
UNIT OF TRANSPORTATION (q_t)

The road investment is characterized by a great degree of lumpiness. If a road is to be built between two points, A and B then it has to be built with a minimum width, to facilitate the motor traffic and to cover all the length from point A to B. A road with half width or half length is useless; it is an all or nothing proposition. In addition, the capital required for road construction and maintenance is quite substantial. The construction cost of the road may vary anywhere from $70,000 for an earth road to $1,000,000, for an expressway and up to $3,000,000, for an elevated expressway per lane per mile. The absolute capital requirement associated with the roads are quite significant.

Another important characteristic is that of the irreversibility. Once a road is built it cannot be either stored or transferred from place to place or sold to another market for a price. Therefore, any errors in investment may have serious consequences. The cost of investment or parts of it cannot be retrieved by selling any parts with exception of the right-of-way.

The huge amounts of minimum absolute capital requirements and the irreversibility, attach a great amount of risk to capital invest ent in roads.

The irreversibility of roads may lead us to believe erroneously, that road investment should be treated as a sunk cost, having regard to the fact that roads are designed and built on the basis of an expected life horizon. In effect, society decides to forego some resources in exchange for roads which will give reliable transportation services through their expected life span. The argument for treating pas road investments as sunk costs would be bad if roads continue to provide services beyond their design horizon, society should feel that all costs foregone in the production of roads services have been recovered and that any additional services may be considered to be free gifts. However, the amount of resources foregone in the production of roads might be different if society had a perfect knowledge with respect to road life and road costs cannot be considered sunk costs if society has perfect knowledge about the future utilization. Therefore, the investment in road is sunk cost only if the economic life of the road is shorter than the expected or design life. There are sunk costs only in the sense that there is an unexpected excess capacity. Only with reference to the unexpected excess capacity should the concept of sunk costs be analyzed. As long as the facility is fully utilized and new investment plans are made the cost of the

facility could and should be retrived and should not be considered as sunk. A fallacy is committed when the concept of sunk costs is associated with a facility at the time when expansionary plans for this facility or similar ones are being made.[6]

On the basis of the above analysis the roads may be considered natural monopolies due to the economies of scale over the low traffic volumes, the large degree of lumpiness, and high absolute capital requirements. "Roads are natural monopolies" and therefore "the state must regulate and control them"[7].

Definition of the Road Output Unit

The question of the output unit should be analyzed in terms of the road services provided and also in terms of the demand function of the consumer.

The consumer primarily demands physical movements of trips of himself, or of goods with a certain amount of speed, frequency, safety and comfort, independently of the mode. A great part of the transport market is provided by the road due to its economic and technical characteristics. It is the most efficient method of transport for at least some of t he urban trips for people and goods. The demand

[6] i.e. No part of the Toronto International Airport can be a sunk cost when plans are being made for the construction of another Toronto International Airport.

[7] A.A. Walters, The Economics of Road User Charges, The National Bank for Reconstruction and Development, John Hopkins Press, 1968, p. 74.

for road transport can only be met by a joint supply of vehicles and roads. The trip is the joint product of both these factors. In order to satisfy the demand for trips the consumer has to make different kinds of decisions at different time periods. For example, assume a consumer X who owns a passenger vehicle in order to satisfy his demand for private trips, with some amount of comfort and flexibility.

(a) He has to replace his vehicle every few years.

(b) Annually he has to obtain operating license as well as purchase insurance for his vehicle.

(c) Depending on the length of his trips he has to purchase a certain amount of gasoline.

In different periods, therefore, he may demand a vehicle, seasonal licenses, and gasoline in order to satisfy his present and future consumption of trips. His demand function may be thus disaggregated into three demand curves, the first two being associated with the availability for road transport.

Similarly the market for road services may be broken down on the basis of their frequency. Primarily there is a demand for capital stock in the form of roads which may last up to twenty years; additionally the roads will have to be maintained to the design service standards i.e. with grass mowing and snow removal.

There is another class of services which is related to the number of vehicle trips i.e. maintenance of road pavement and shoulders. The first two types of road services, therefore, are related to the demand for availability of road transport where the third one is related directly to the actual number of vehicle trips. Hence the availability of road transport includes the capital stock and operation of vehicle and roads. The market for vehicle trips as they take place, is mostly related to maintenance and operation of vehicle and road, as results of these trips.

The above indicates that the choice of road output unit is not an easy task i.e. it could be the stock of roads in terms of miles or expenditure , it could be the seasonal availability of road services or the actual vehicle miles that take place. Other complications may be introduced when we consider the different types of road users. The large commercial vehicle operators may demand a wider and stronger structure than the smaller passenger vehicle operators and may also demand a different level of road services in general. This complication results from the fact that there is a joint road consumption by consumers with different demand functions. The road is not a good such as steel which

may be produced to different specifications of quality and dimensions. The economic characteristics necessitate the production of one kind of road for all users. The ton-mile and passenger-mile units are often used for the measurement of road output in many circumstances.

Roads cannot be analyzed in terms of one specified unit; nevertheless, it may be useful at times to think of the output unit of the road in terms of vehicle-miles-quality. The consumer of roads usually demands vehicle trips (its proxy being vehicle-miles) with a certain amount of quality in terms of comfort and speed.

Substitutes and Compliments of Roads

The function of roads is to provide road transport and therefore there is a great degree of complementarity of roads and vehicles. Any policy that might effect the road market will equally effect the vehicle-market. Any government policy to subsidize the roads has a significant impact in the market for vehicles as well. Effectively some of the subsidy, at least indirectly is transferred to the vehicle industry.

Strictly speaking roads per se do not have any substitutes. Only road transport may be substituted by other transport modes i.e. rail, air, pipeline, marine. In the urban centres the road transport has captured most of the market. The inter-urban transport market for passengers is shared with air and rail primarily. The market for commodities

is shared with rail, marine and pipeline and to a small extent with air. The commodity transport mode is chosen on the basis of transportation cost as a percentage of the value of the commodity to the users. Any commodity of high value in terms of its weight and volume, such as diamonds, may be moved by air primarily. The above decision of which mode to choose will be influenced also by other factors such as speed and safety.

In the inter-city passenger transport, given sufficient distance, the business and high income classes use primarily the air mode. In the passenger travel, the roads may have the comparative advantage up to 100 miles, the rail between 100 and 300 miles, and the air for any distance beyond 300 or 350 miles.

III THEORETICAL ASPECTS OF ROAD PRICING

In order to appreciate the magnitude of the problem in road pricing and the need for a clear definition of the terms of reference some simplified examples will be presented. The issues of the single vs. many road users, and methods of road financing will receive attention.

The Single User

A consumer X requires transportation from his business to his place of residence. Transportation may be provided by a vehicle and a road. Both these goods are required jointly for the provision of any amount of transportation. Assume only one kind of vehicle in the market - Pinto, and one type of road - earth. Transportation then can only be produced in one form, the factors of production being the Pinto and the earth road with zero elasticity of substitution between them. The supply and demand condition for transportation (t) are shown in Figure 8. X cannot make use of an additional road and or vehicle. It is an all or nothing situation with a sharp discontinuity for demand and supply at one unit of transportation output, consisting of one vehicle and one road.

The supply consists of the cost of the car and the road. The operation and maintenance of the car and

the road are assumed to be zero. The equilibrium price P_e is indeterminite; and $P_d \gtrless P_e \gtrless P_s$

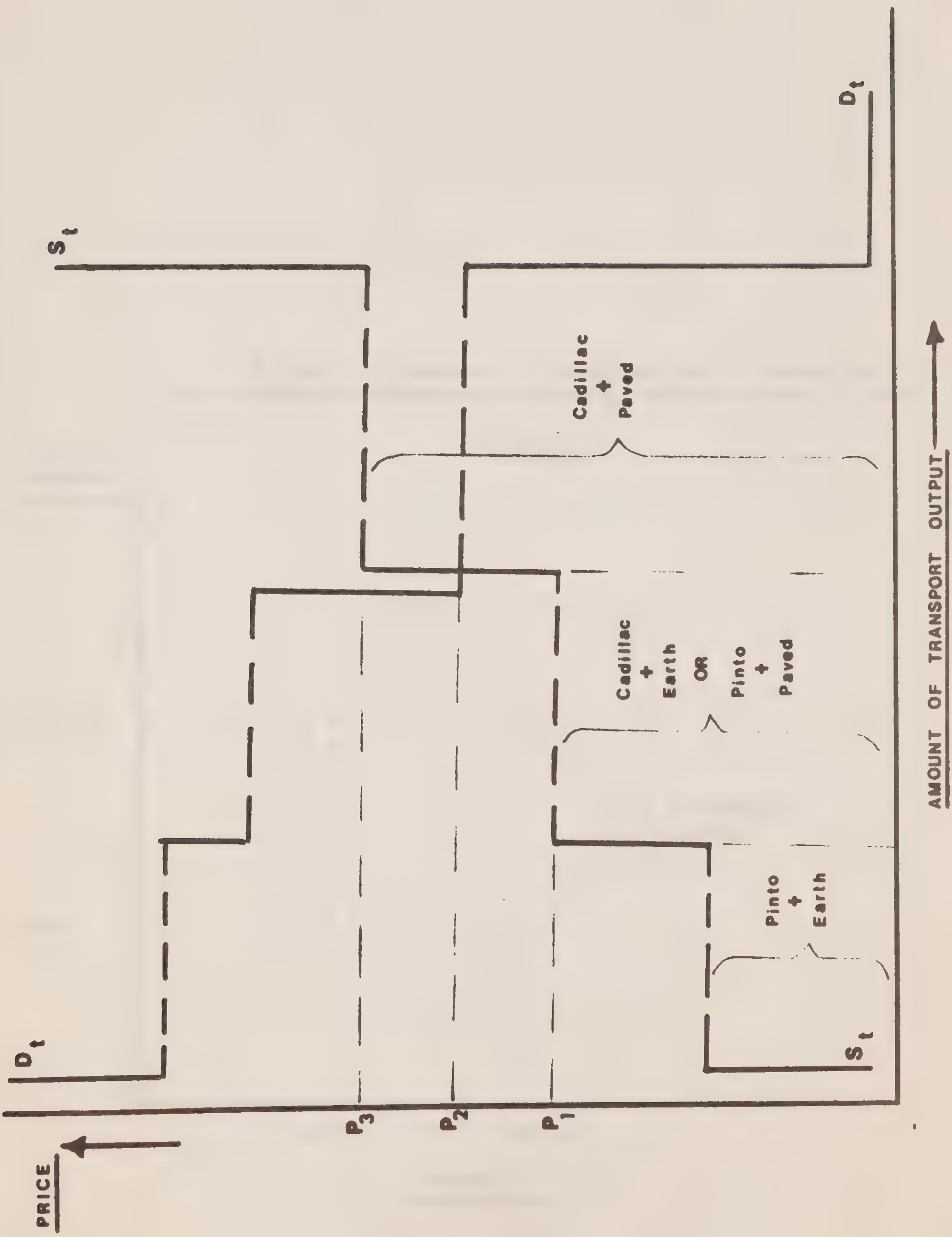
If X is now faced with additional alternatives of owning a Cadillac and building a paved road then he could improve the quality of his transportation; he could buy "more" transportation. His new supply and demand condition one shown in Fig. 9, which result from the production function shown in Fig. 10. . In reality there is a variety of roads and vehicles available to X with different cost characteristics. The demand and supply condition are as in Fig. 11. The equilibrium in Fig. 11 is at point e. X would purchase q_e at price P_e which would be the cost of the vehicle and the road.

The equilibrium price P_e and output q_e satisfies the conditions of efficient allocation of resources. Any other price would result to inefficient allocation of resources, given X's income, his demand, and the market supply.

Financing the Road System

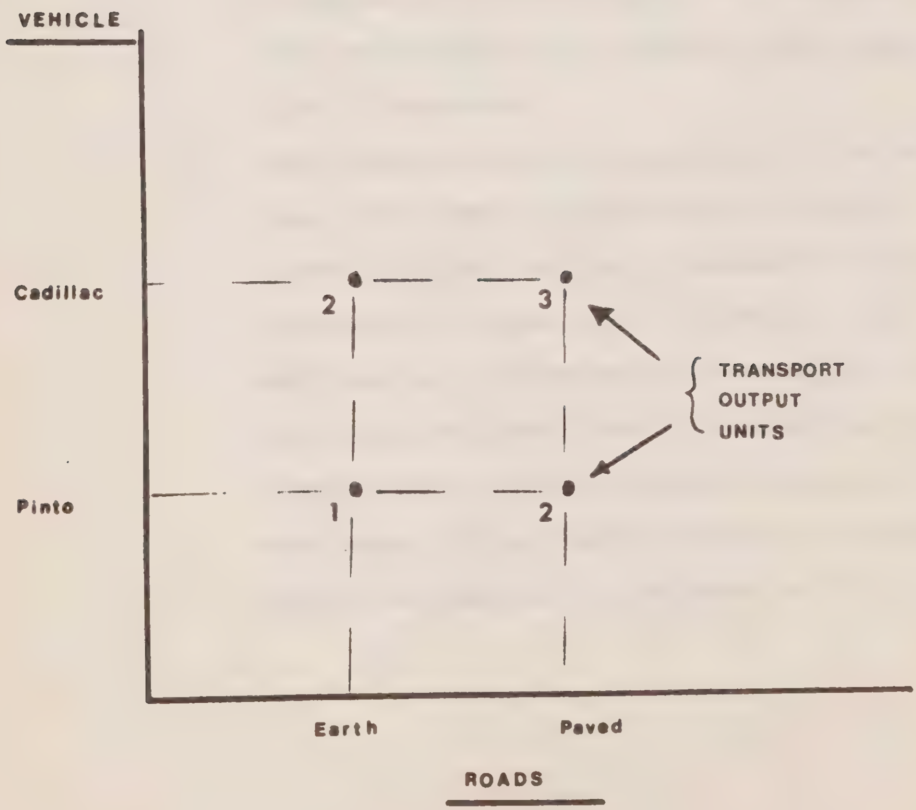
Suppose X finances the vehicle price which is assumed to be optimal, and the Government builds the road and decides to finance it out of general taxation. How would this effect the efficient allocation of resources?

FIG. 9


PRICE
AMOUNT OF TRANSPORT OUTPUT
D_t
S_t
S_t
D_t
P_3
P_2
P_1
Cadillac + Paved
Cadillac + Earth OR Pinto + Paved
Pinto + Earth

Road Transport Production Function

FIG. 10



There are two issues that should be examined:

(a) By constructing the road out of general funds the Government in effect redistributes income from the other taxpayers to X. This cannot be evaluated on pareto grounds. It is a mere income distribution and does not necessarily distort the efficient allocation of resources. It would only result in a shift of X's demand curve due to the income effect as shown in Fig. 12 from DD to D'D'. The new equilibrium point would be e' resulting in higher price and output for transport which does not violate the criterion efficient allocation of resource.

(b) This income transfer is made in a form of a road. The demand curve would not shift upwards but only slightly downwards due to X's loss in income due to taxation. In addition he is faced with a new supply S'S', to the right and down from SS because his new supply curve does not include the cost of the road since it is freely provided. Only the cost of the vehicle is included in S'S' in Fig. 13.

FIG. 11

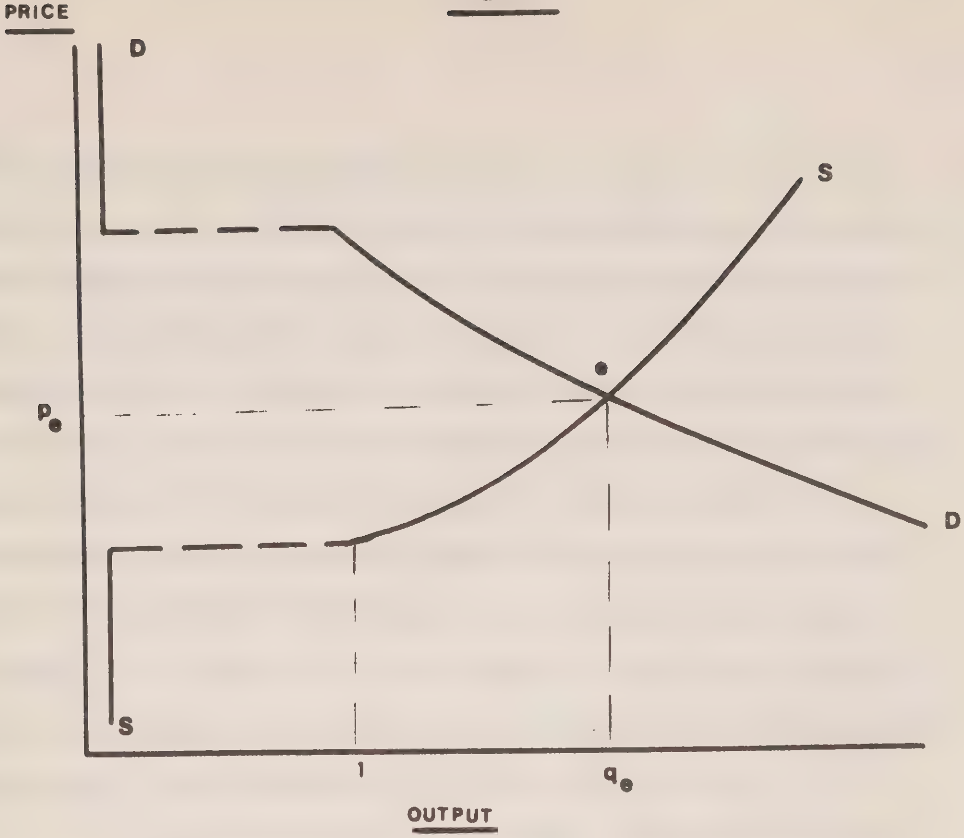
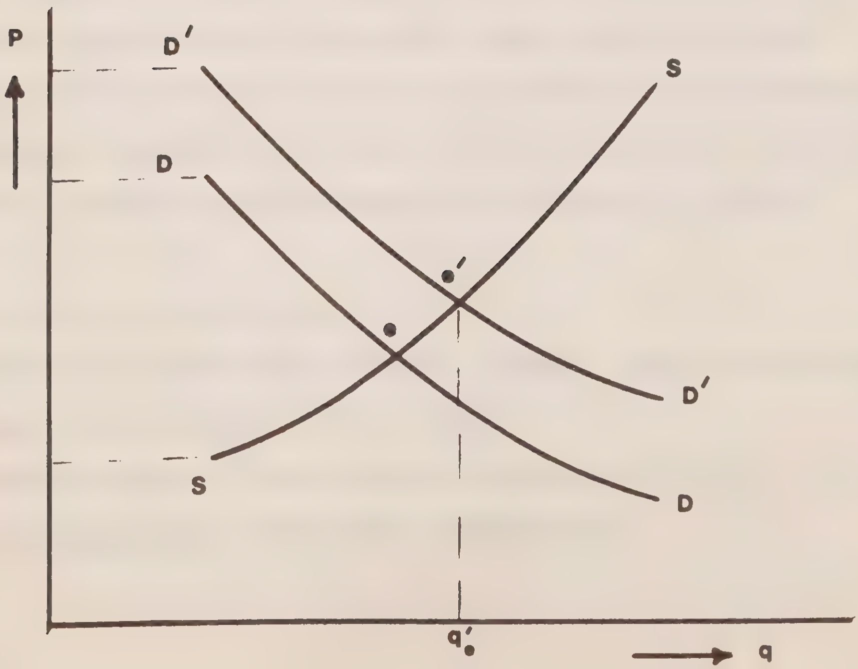


FIG. 12



The new equilibrium point is at e''. Point e" reflects only the private costs that X is faced with and, which is less than the total (social) cost which would include the cost of providing the road as well*. This would lead to misallocation of resources because X can not choose his own mix of road and car and select one that maximizes his benefits and his transport output. Misallocation of resources could be avoided only in the unique situation where the optimal output q_e' in Fig. 12 is equal to q_e'' in Fig. 13. This is the case where X would have chosen to build the same type of raod as provided by the government, given the income redistribution as in (a) above.

Suppose** now the government charges X directly for the cost of a road and demands a long term payment of $2,000 or an equivalent annual rent of $100. If X would have chosen to build the same type of road for the same cost in the absence of the government then we say that this road maximizes X's benefits and also meets the criterion of efficient allocation of resources and the project is worthwhile. X would be indifferent to the form of payment.

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* This is a case where marginal private costs are significantly less than marginal social costs.

** Some element of the following example are based on A.A. Walters, The Economics of Road User Charges p.18

The cost of transportation to him is the present value of costs he would have to pay for the vehicle and the road (independently of the form of payment in form of lump-sum or annual rent). His supply curve is a locus of points of the discounted values of the vehicle and road. So far, we have neglected the amount of utilization of the road and vehicle. Transportation was defined in terms of quality and availability from his business to his place of residence. X jointly with the quality of transportation, also demands number of journeys. But since the cost of the individual journeys is assumed to be zero it did not enter our formulation. This is shown in Figure 14. The individual will undertake 1000 journeys annually at a zero price per journey. Let us now assume that the government decides to retrieve the cost of the road from X by charging him on the basis of number of trips instead of by a lump sum payment of $2,000 or annual rent of $100. This can be achieved by introducing a government function F.(G) with hyperbolic shape. Any rectangle to this axis under the hyperboloid should be equal to $100 as shown in Figure 15. Any tolls between $0.2-$1.00 will produce more revenue than required and any tolls outside this region would produce less revenue. The break even solutions are at P = $1.00, and P = $0.2. Suppose the government chooses the toll $0.2 because it covers the costs and also provides more trips to the individual. Would this be an efficient solution? The conditions of the supply and demand in Figure 11 are not changed since the discounted

FIG. 13

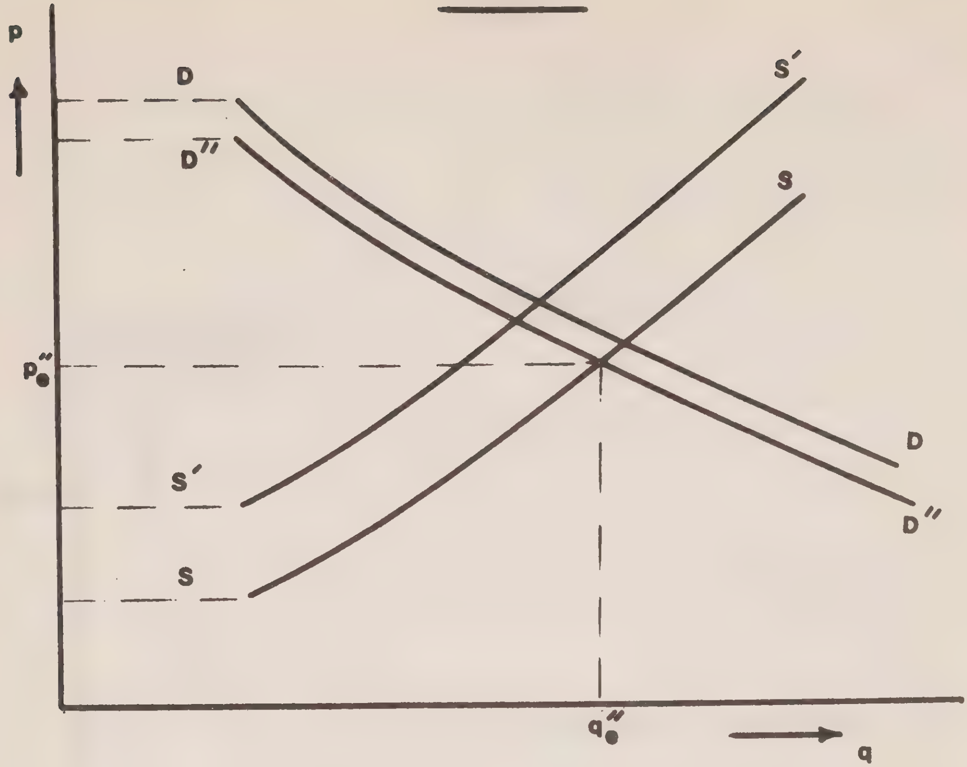


FIG. 14

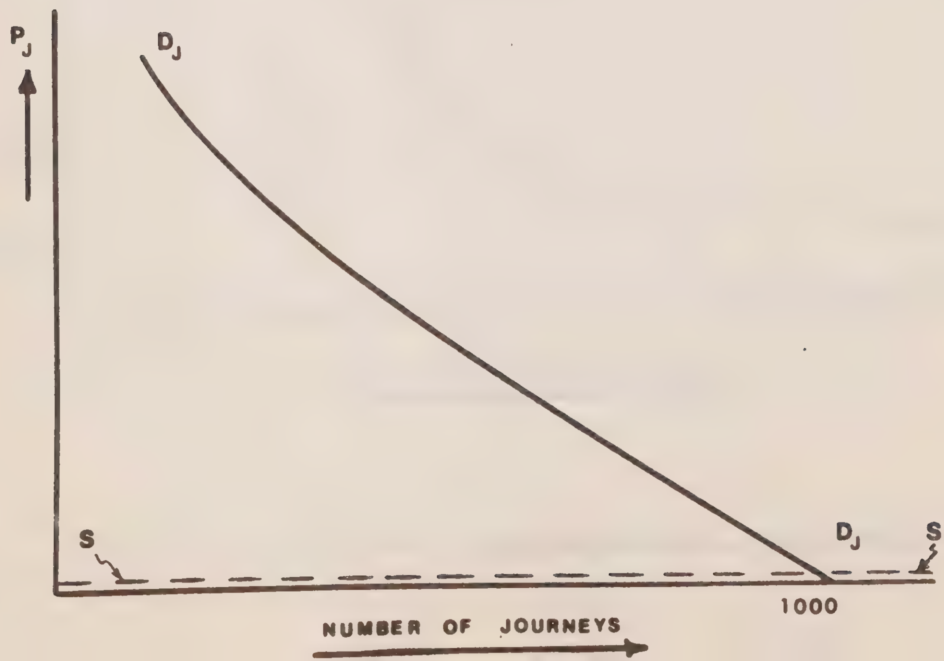
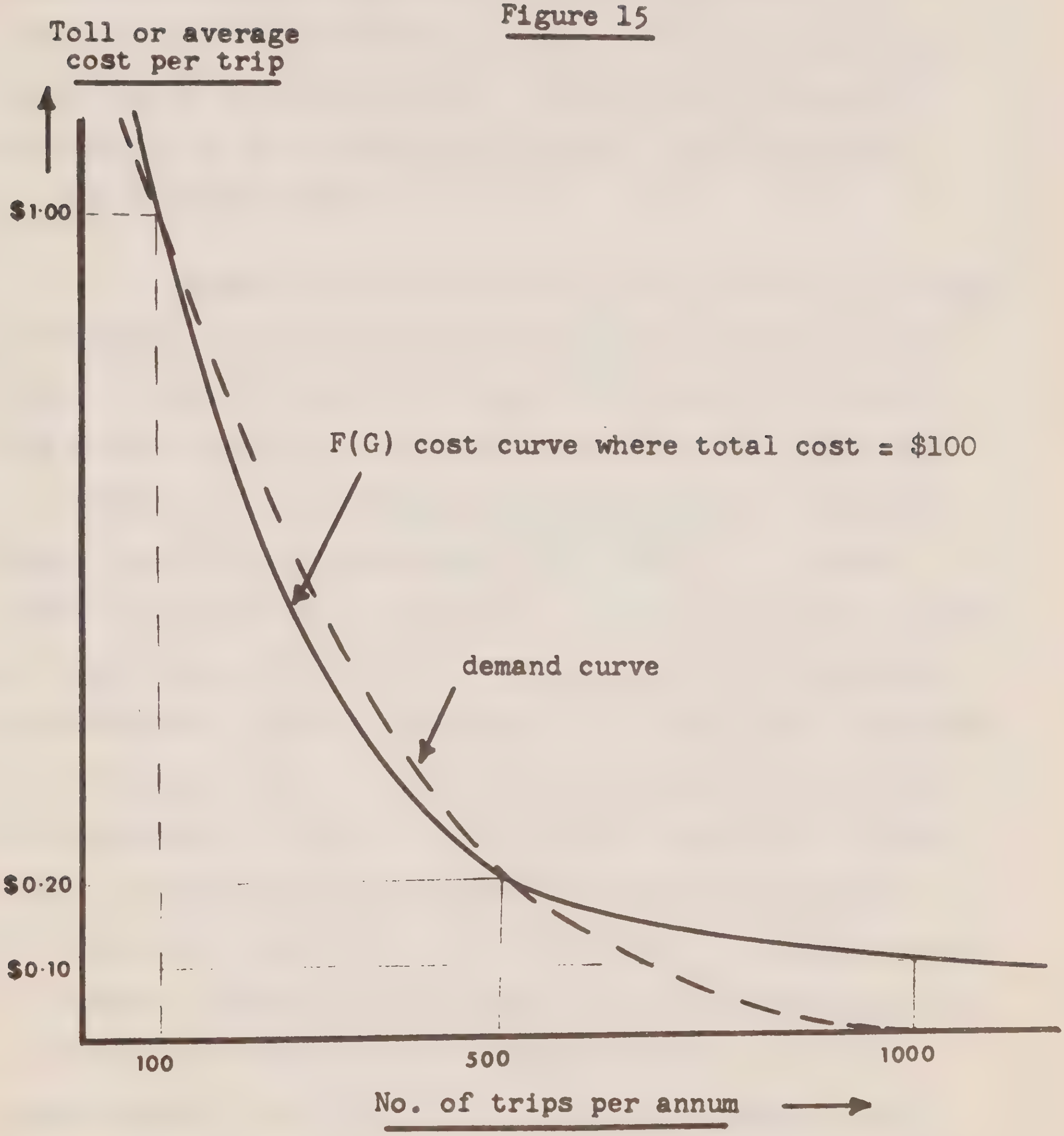


Figure 15

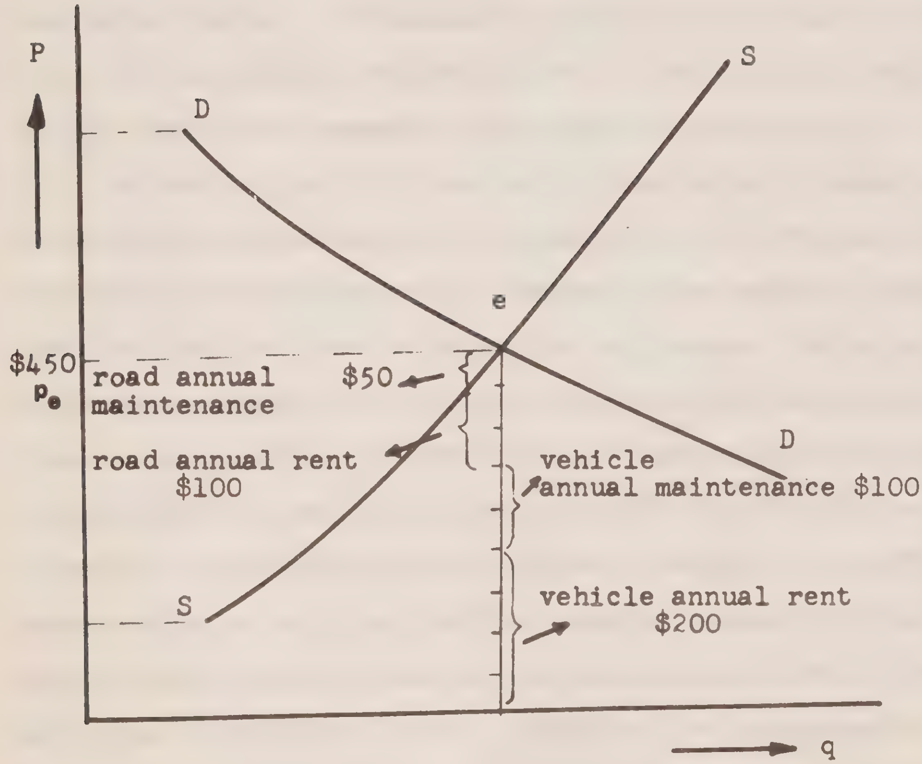


Source: A.A. Walters, The Economics of Road User Charges

value of the road payments are the same independently of the form of payment. Under a lump sum payment X would undertake 1000 trips per year. Under the new scheme of payment per trip X takes only 500 trips per year. By lump sum payments, therefore, X enjoys 500 extra trips per annum and no one else suffers. Clearly the toll method of pricing is an inefficient one, given the assumptions of zero running costs.

Suppose we drop the unrealistic assumption of zero maintenance and operations costs for the vehicles and the road. X will be faced with higher transportation costs. The supply consists of the capital costs of the road and the vehicle, and the maintenance and operations costs for both, Fig. 16 shows his equilibrium condition in annual terms. He knows that in addition to annual rent for vehicle and road, he will be faced with maintenence and operations expenditures. This is reflected in the individual components of the supply curve. In this case we assume that he pays an annual rent of $200. for the vehicle and $100. for the road. The maintenance and operations cost will be $100. for the vehicle and $50. for the road and it is function of the number of annual trips. Therefore, the supply curve is a function of the number of trips as well as the other fixed factors. Once he decided to provide himself with

Figure 16


P
D
S
e
$450
p_e
road annual
maintenance
$50
road annual rent
$100
vehicle
annual maintenance $100
D
S
vehicle annual rent
$200
q

transportation during the year, the costs of the vehicle and the road are not escapable any longer. The only escapable costs are the ones reflected on the number of trips which are the maintenance and operations costs. Now he is faced with a different set of equilibrium conditions, reflected in Figure 17. The supply curve consists of the escapable costs of the road and vehicle per trip which are the only escapable costs. The escapable costs of the vehicle per trip is 10¢ and the escapable cost of the road per trip is 5¢, the total escapable cost per trip being 15¢. If X is charged with 15¢ per trip, then he will undertake a a thousand trips annually. Suppose now the Government decides to recover this road damage or the marginal cost of the road per trip not by a charge per journey but by an equivalent charge of 5¢ X 1,000 trips = $50. This would not change the equilibrium conditions in Figure 16 since he is faced with the same annual supply curve; but in Figure 17 the consumer is now faced with a different supply curve S'S' which reflects only the vehicle running costs. The new equilibrium condition now is 10¢ per trip and the number of trips is raised to 1,500. Assuming the road marginal cost per trip is the same, the increased number of trips will increase the amount of damage caused on the road per trip from $50 to $0.05 X 1,500 trips = $75. The Government will therefore demand that X pays $75 annually. This will

be reflected in an upward shift of the supply curve in Figure 16, the amount of the shift will be $25, shown in Figure 18. The final equilibrium is at e'. At e' the optimal quality of transportation is inferior i.e. he demands an inferior mix of roads and vehicle. This may feed-back into the number of trips and shift his demand curve for annual trips . The new equilibrium point is now between 1,000 and 1,500 trips annually. Including therefore the road running costs in the annual lump sum payment will result in an inferior mix of roads and vehicles, and an increase in the number of trips taken during the year, than X would have chosen if he was faced with the actual fixed and escapable costs, relevant to his decision for transportation. This leads to a misallocation of resources. The degree of misallocation is a function of the elasticity of the supply and demand curves. The above leads to the conclusion that optimality may be achieved when X makes a lump sum payment for the capital cost of the car and the road and he is also faced with the total real cost of each trip with reference to the maintenance and operation of the vehicle and the road (which are caused by the trip). In other words, the principle of escapability, where X is responsible at any time in paying for the escapable costs only, will lead to an optimal allocation of resources. At the time of purchase of the vehicle and the road, these costs

FIG. 17

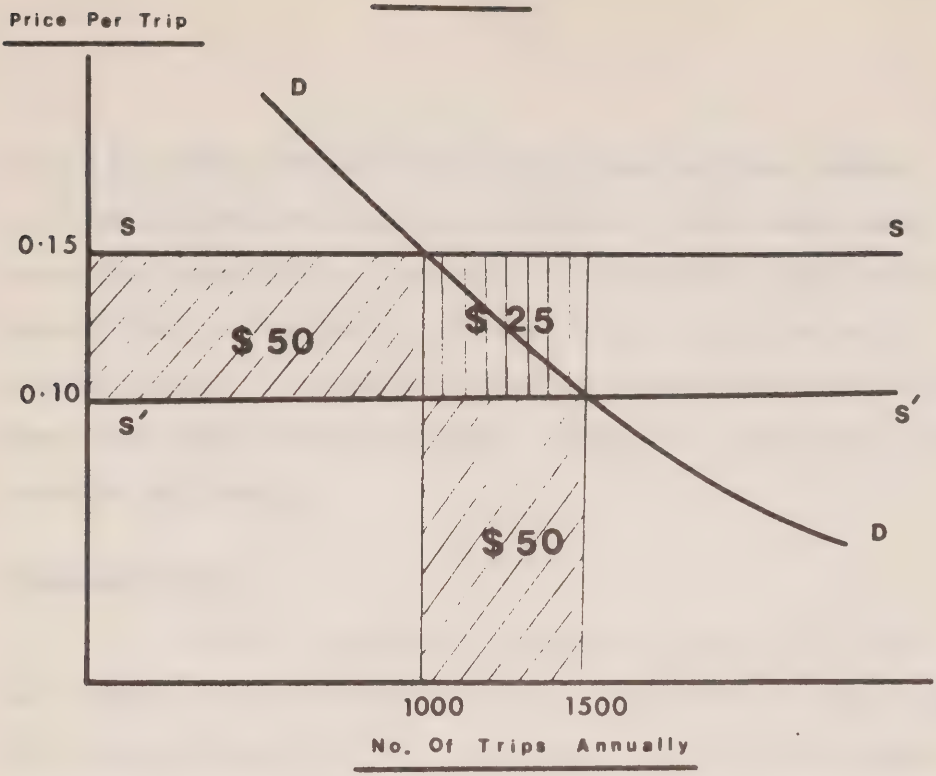
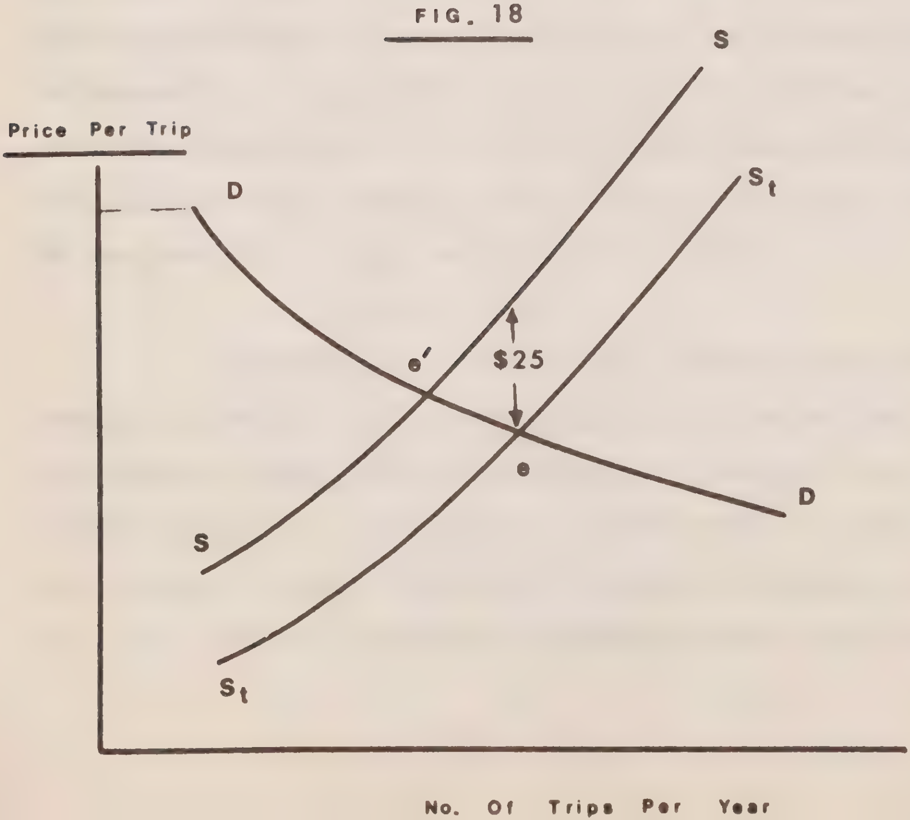

Price Per Trip
D
S
S
0·15
$ 50
$ 25
0·10
S′
S′
$ 50
D
1000
1500
No. Of Trips Annually

FIG. 18


S
Price Per Trip
D
S_t
e′
$25
e
D
S
S_t
No. Of Trips Per Year

could have been escaped if X would have decided against utilizing transportation in this form. This would have been the proper time to pay for these costs. Similarly he should pay for the trip costs but only on the basis of escapability. He should be able to avoid trip costs if he does not wish to take the trip. This will result in overall maximum efficiency.

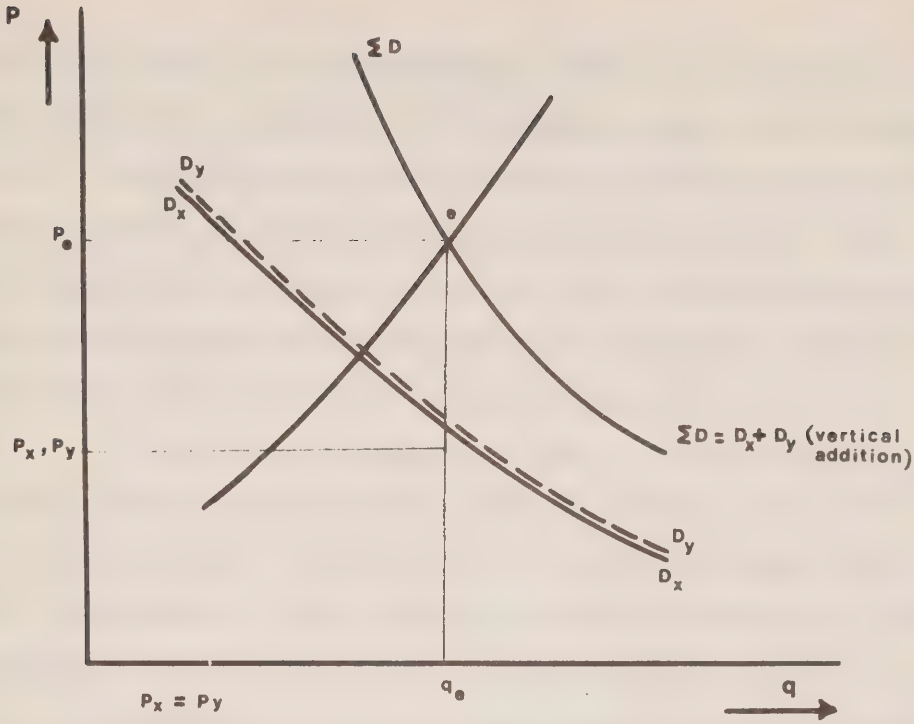
Multiple Users

So far it has been concluded that if X is the only user of the road then he should pay for all the costs. If there are instead, two road users X and Y with known and identical demand curves, then the equilibrium price in road quantity is shown in Figure 19. This is the case of a group good which is jointly supplied to both users and consequently the aggregate demand curve is computed by the vertical summation of the two individual demand curves. The optimum total quantity and price for the road is qe and Pe respectively. Each user will pay a price

$$P_x = P_y = \tfrac{1}{2}P_e$$

In practise, the individual demand curves are rarely the same. It is more realistic to assume that equilibrium takes place as in Figure 20, where Y has a higher demand for roads than X. In this case X would pay a price, Px, Y would pay Py and the aggregate price $P_e = P_x + P_y$. This is feasible considering that X and Y are

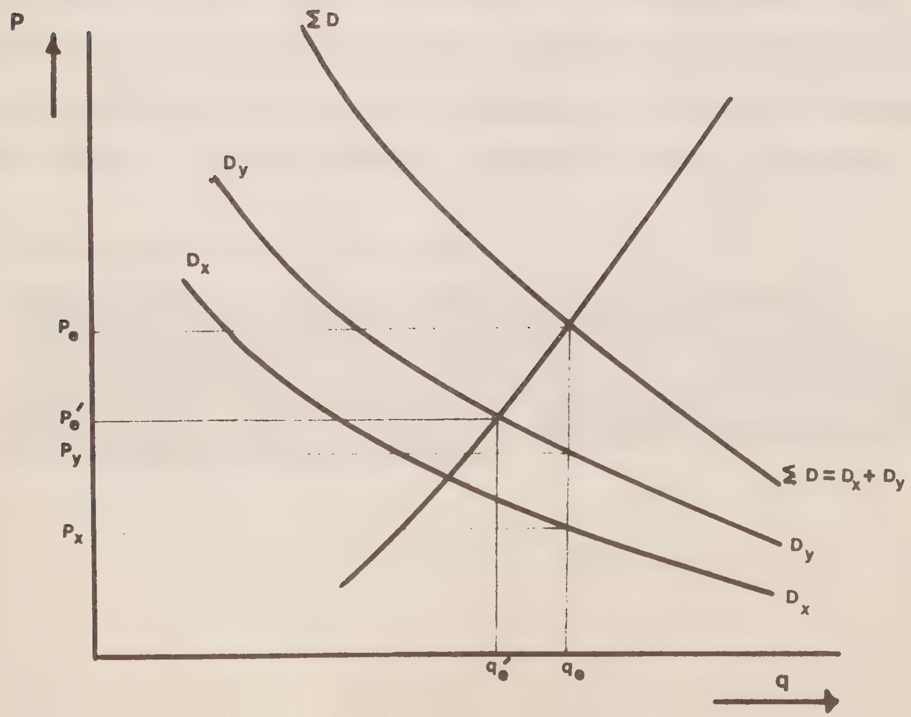
FIG. 19



$P_x = P_y$

$P_e = P_x + P_y$

FIG. 20



willing to make their preferences known. If X knows that Y will build the road even in X's absence, then X may choose to hide his preferences, and say that he has no use for the road in order to avoid paying for any part of it. Y now will build the road at an output of q_e' and pay a price p_e'. This road is now equally available to X as well, although he has not contributed towards it's construction*.

This is not unique of roads. It is reflected in many other economic goods, such as country clubs where it is impossible to determine the individual demand curve for these goods. Anyone wishing to join a country club pays an annual fee of, say, $500. This fee covers most of the services provided by the club, such as golf courses, swimming pools, etc., and which costs are inescapable in the short-run, in other words they are not a function of amount utilization of the club. This fee in the aggregate will cover the long-run costs of the club which is a group good. It distributes equally to all members the burden of inescapable costs. The same concept applies to most of industry , i.e.

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* Assume here that Y has no way of either policing or controlling the utilization of the road by X. Even if he could, the road stock is now given and is independent of the amount of utilization, therefore, any controlling costs would burden Y additionally. Y may choose to let X utilize the road as long as X does not contribute to additional costs of congestion and maintenance.

all escapable and inescapable costs in the production of automobiles is reflected in the final price.

The same approach may be applied in the case of roads if the individual's preferences are not known. All users pay the same price (an entry club fee) to the road system independently of their amount of utilization.

This problem may get more complicated if Y is a heavy truck operator instead. In order to provide the same road services as previously, the road bed will have to be built much stronger and with a wider pavement and shoulders. On the basis of escapability again, all these additional costs should be allocated to Y alone since they were made necessary due to his bigger vehicle. All initial costs, therefore, should be shared equally by all vehicle operators, and all additional costs should be allocated to vehicles that cause them.

The same approach would apply to all other escapable costs such as snowplowing, grass mowing, etc.

The treatment of escapable costs associated with the vehicle trips presents a problem. In the absence of the truck, the car causes road maintenance for each vehicle-mile travelled, but after the introduction of the truck, the road is of superior strength and therefore the damage due to the car on the road is smaller than it would have been before. For consistency, if the car pays its share of the road capital costs as discussed above, then it

should also pay a charge per vehicle-mile that it would pay if the road was built to its specifications--in the absence of the truck.

For efficiency, it would be more preferable for the car to share more of the capital cost of the road and pay towards the maintenance, an amount equal to the escapable costs of the trip. This alternative is more appropriate within our framework but the empirical approach to be taken will depend on the amount of information available.

Classification of Road Costs

Road costs will be classified by the principle of escapability on the basis of the vehicle-journey into escapable and inescapable costs.

Escapable are the costs that are directly related to the number of vehicle-journeys. They may be escaped in the absence of vehicle trips and cannot be escaped when vehicle journeys do take place. These are the costs associated with the road damage caused by the vehicle as it travels over the road. They may be approximated by the maintenance expenditures of the pavement and the shoulders. More specifically the escapable costs are a function of number of miles travelled, engineering characteristics of the vehicle i.e. weight, number of axels and type of tires,

and the type of road surface. All escapable costs may be identified and allocated directly to each vehicle journey.

Inescapable costs are those that could not be escaped or varied at the time that the decision is being taken whether or not to take a particular vehicle journey. The inescapable costs include elements of various lifes, such as the road capital stock which may be replaced over 10 - 20 years, grass mowing, maintenance and replacement of signs and snow-plowing which take place seasonally or annually. None of these costs are escapable with reference to the vehicle trip and they are collectively supplied for all vehicle operators. They cannot be stored, they are irretrievable, and are always available to all users. These services provided may be a measure of the quantity of roads, and of the quality or level of read service such as type of surface, lighting, signs, etc. available to the users. The identifieation and allocation of this cost to the users is not a simple matter. We are faced with some difficulties similar to the ones in the allocation of costs of the "public good". As in the case of the single user above, all inescapable costs can be allocated to the users by either of the following two ways: a) allocate each type of cost as it takes place i.e. the road stock can be allocated to the users every twenty years only and the seasonal snow plowing costs can be allocated to the users every season;

b) allocate all inescapable costs and lump them together in one single payment. The principle of escapability will be fulfilled if the timing of the payment period is the same as the life of the periodic cost element with the shortest life or with the highest frequence of occurance. Accordingly, this road payment or rent should be made not once every twenty years, but onee every season.

On the basis of the efficient allocation of resources as interpreted in this paper, all road costs should be allocated to the vehicle as a function of the vehicle characteristics. The vehicle trip escapable costs will be allocated directly to the vehicle to satisfy the condition of efficiency. All inescapable costs should also be allocated to different vehicle groups as a function of their dimensions to satisfy the condition of efficiency. The difficult problem, conceptually at least, arises in the allocation of incescapable costs among the vehicles in each group with similar engineering characteristics. Admittedly this allocation cannot be made on strictly efficiency grounds since we do not know the preference function of each vehicle operator. It has been suggested above that this allocation should be made equally among identical vehicles. This does not necessarily fulfill the condition of efficiency. It is rather a value judgement

based on equity considerations due to lack of any better alternatives.

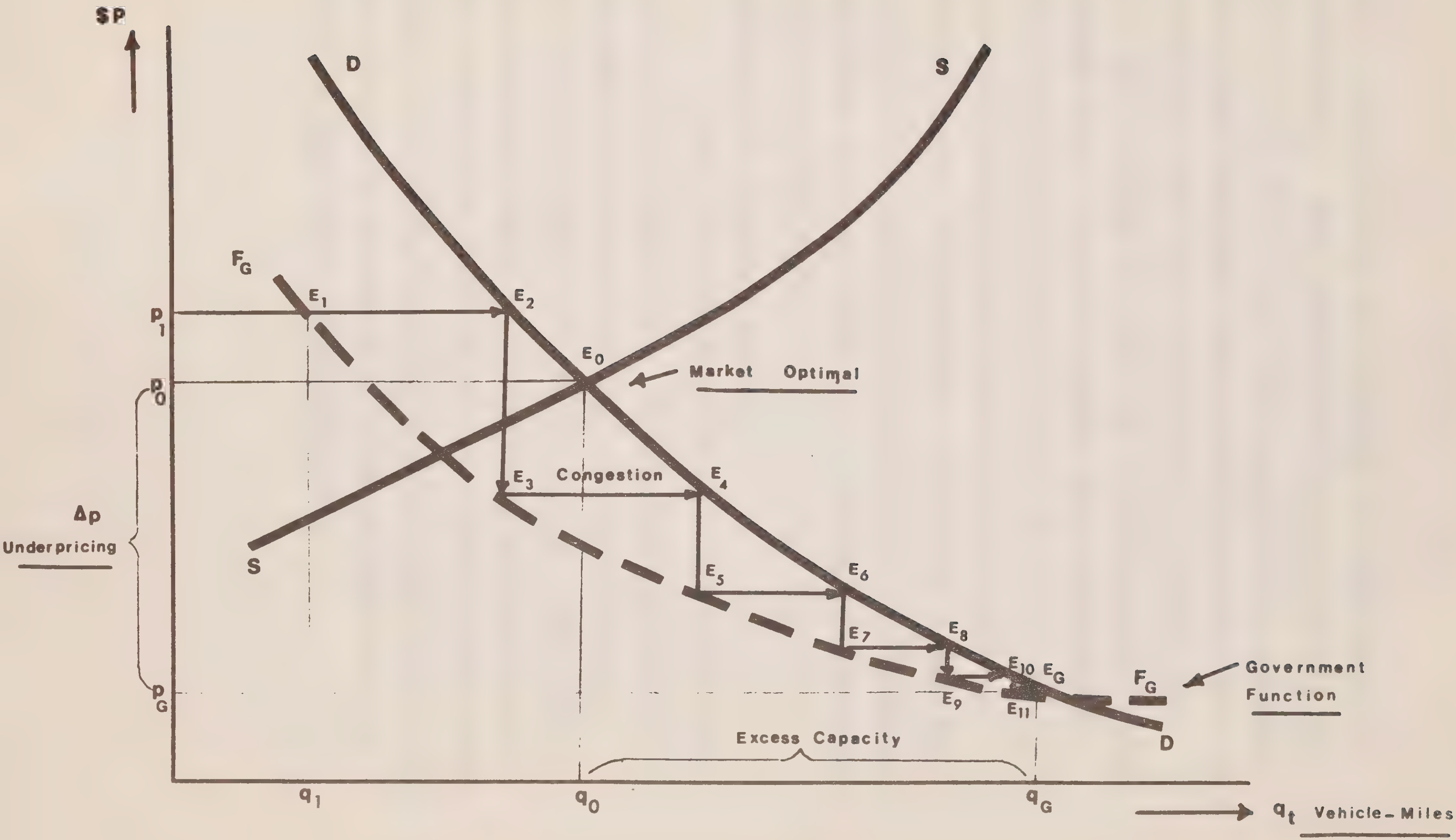
Allocation of Road Costs Among Users and Non-Users

There are some road elements that benefit only the non-users and others that benefit users and non-users jointly. For example, the sidewalk benefits only the non-users, that is the pedestrians, where the right-of-way of the road benefits both groups in the urban centres. All these elements should be identified and allocated appropriately on the basis of escapability, i.e. not all of the stock of right-of-way should be allocated to the road users. In the absence of the vehicle some right-of-way would exist between land properties for access in the urban as well as in the rural areas. This is not just a hypothesis; in many towns in southern Europe there are roads inaccessible to vehicles and used only for land or property access. The identification and allocation of this kind of costs will be the first step in our empirical analysis.

IV - ANALYSIS OF PRESENT ROAD PRICING IN CANADA

It would be appropriate at this stage to analyse the present road pricing policies in Canada in view of what has been said so far. The roads are the responsibility of the provincial and to a lesser extent of the municipal governments. The pricing of road services is totally a provincial responsibility. The authorities therefore are responsible for supplying as well as pricing the roads but there is a lack of coordination between these two activities. An optimal market mechanism would set the price and output of road services at the point of intersection of demand and supply; but the consumers of road services are faced with prices set up by the government authority on the basis of some government function f(g) which is independent of the real supply curve. This situation is shown in Fig. 21. The Government sets the level of prices. The market optimal point is shown at E_o. Suppose initially there are q_1 road services provided. The price is set by the Government function F(G) at p_1. At price p_1 the consumers demand q_2 road services, resulting in excess demand (shortage in supply) of $q_2 - q_1$. The government department responsible for supplying roads sees this shortage of roads and tries to fill the gap by building more roads and eventually reaches q_2. At q_2 the prices drop to p_2 by the Government function

FIG. 21

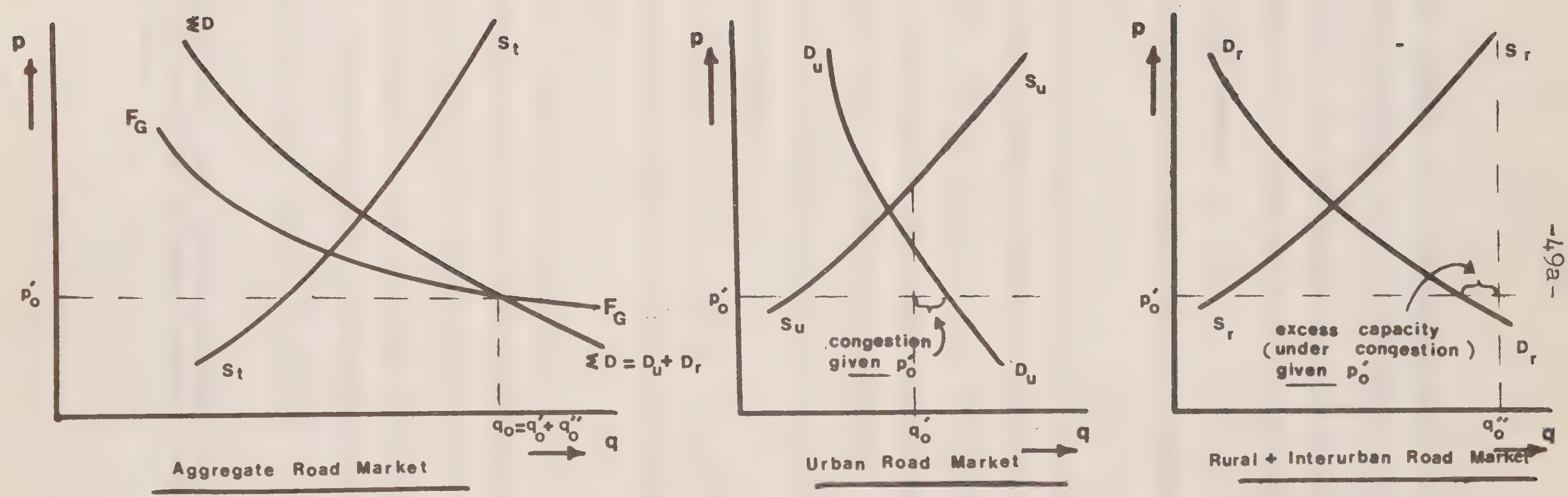

$P
D
S
F_G
E_1
E_2
E_0
Market Optimal
p_1
p_0
E_3
Congestion
E_4
Δp
Underpricing
S
E_5
E_6
E_7
E_8
E_10 E_G
F_G
Government Function
p_G
E_9
E_11
D
Excess Capacity
q_1
q_0
q_G
q_t Vehicle-Miles

F(G). This continues until finally the equilibrium is reached at E_G. This equilibrium is not the optimal one. At this point there is an excess supply of road services. The way this Government function was drawn will result in a lower price and higher output than the optimal one. It is not necessary that the F(G) be of the shape or slope as shown here. A similar argument may be developed by changing the slope or shape of F(G). At present the same pricing policies hold for urban as well as interurban and rural roads. The Government policies at present may result in over-congested urban centres and undercongested rural areas as shown in Fig. 22. It is obvious from this illustration that different sets of prices should be formulated for different markets.

This is an indication of the inadequate understanding of the road market. The road market cannot be considered as the whole province. Different pricing policies should apply to different regions. Basically the road market should be disaggregated in urban, rural and interurban and different policies should apply in each market. The present system fails to make this distinction and also does not provide us with the necessary data to develop an appropriate pricing mechanism.

FIG. 22

Division Of Road Market



At the present the road planners in Canada are not concerned with pricing policies. They operate within a road budget voted by the Government and with prices determined externally. There is hardly any coordination between pricing and amount of capacity available. Only this type of coordination would lead us to optimal investment decisions.

No effort has been made so far, to my knowledge, to adjust prices in order to improve efficiency. The interested authorities do not have any information on either gross or net road stock, annual costs and revenue of the road system in a comprehensible manner. They have data on annual expenditures and revenue which is incomplete and misleading.

The next step of this chapter is to study and evaluate the specific pricing policies in Canada today.

Motive fuel tax

This is a specific tax per gallon of motor fuel. For most provinces the tax for diesel and gasoline differs. This is the only form of road revenue related to the road utilization and as such is the only one related to the excapable costs. This form will be examined on the basis of its optimality i.e. its degree of neutrality.*

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*Neutrality is the least possible interference in the decision making process or in more general terms, minimum cross-subsidization.

The escapable vehicle-trip costs is the damage caused by the vehicle on the road. This is a function of the vehicle weight-miles and more specifically of the axle weight-miles. How is the motive fuel tax related to this damage?

The fuel consumption efficiency decreases as the age of the vehicle increases. Therefore, the old vehicle pays a high price for the same vehicle-trip than a new vehicle although the damage caused is the same. Therefore, this tax discriminates against old vehicles*.

The efficiency of fuel consumption is lower on vehicles with bigger engines (given same axle weight and no. of axles) and therefore the fuel tax discriminates against vehicles with larger engines. The fuel efficiency is much higher on paved than on lower quality roads. Hence users of poor roads pay higher fuel taxes for the same trip. The damage caused on the earth roads due to a given vehicle trip is higher than the damage caused to gravel. The least damage is caused on the paved road which is the most expensive to build. But since the rest of the charges (licenses) are not dependent on the type of road, there will be a great pressure on the authorities

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* If it is assumed that older vehicles are owned by lower income groups then the fuel tax is regressive as well.

to replace the earth and gravel roads by paved roads. This will result in lower tax revenues and better and more expensive road facilities. The end result will be higher overall road expenditure and lower revenues per vehicle than before. The drop in revenues occurs because all license fees stay the same but fuel taxes drop.

The diesel tax is higher in most provinces than the gasoline tax. This is in the right direction because diesel efficiency is higher than that of gasoline. One gallon of diesel will result in a higher utilization of roads than the gasoline and therefore it requires a higher charge per diesel gallon. The efficiency of fuel varies with the speed and this may introduce further misallocation of resources. In this area it discriminates against the use of highly congested roads since the charge per mile would be higher. This might be in the right direction because the vehicle congestion causes high social costs. But the increase in the gas consumption in congested areas is not necessarily the 'right' price for the significant social costs due to congestion.

The specific tax on fuel discriminates against the less costly fuel blends. A given percentage degrease in the price (not of tax) will result in a decrease in the after tax price which is smaller for the higher priced blend. Suppose P_1 and P_2 are the prices of gas to the consumer, and $p_1 > p_2$. "t" is the tax applied to both blends. Assume

that the change in the price net of tax is x%, then the gross % drop from p_1 and p_2 is as follows:

$$\frac{(p_1 - t) \times X\%}{p_1} > \frac{(p_2 - t) \times X\%}{p_2}$$

(gross % drop of p_1) (gross % drop of p_2)

Numerically, suppose the cost of producing a low and a high octane fuel is 20¢ and 30¢ respectively, i.e. in the ratio of 1:1.5. If the specific tax of 20¢ is added , then the prices would rise to 40¢ and 50¢ and the new ratio would be 1:1.25, which ratio is closer to 1 than the cost ratio. Therefore, the specific tax per gallon will encourage the use of the more expensive gasoline which requires more costly refining.

Additionally, the specific tax has an impact on the effectiveness of competition. If a dealer wishes to cut gross prices by 10% his revenue would drop by more than 10%. For example, the 50¢ per gallon brand would drop to 45¢ but his net price will drop from 30¢ to 25¢ which is a 16.6% decrease in net price.

The existence of the specific tax discriminates in favour of higher efficiency engines. Hence, it will direct technology into the development of higher efficiency engines to a greater degree than in the absence of this specific tax. The increased technology may lead to higher

private benefits which in the aggregate are higher than the social benefits. This leads to misallocation of research effort. The higher tax in Europe is one of the important factors that led to the development of higher consumption efficiency engines in Europe rather than North America.

The argument in favour of the fuel tax is its simplicity of collection and administration. The fuel companies are responsible for collecting the tax. The provincial governments pay a collection fee of 2½% of the tax revenues to the oil companies.* This tax is paid at the time of purchase of the fuel.

*It is estimated that $25M was paid to the oil companies as commission in 1968 in Canada. It seems to me that this is an amount which exceeds substantially the actual cost of collection and transfer of the tax. Most of the Commission accrues to the oil companies as a pure surplus.

Motor Vehicle License Legislation Fee

All provinces classify the vehicles into three groups - passenger, truck and bus. Further classification is not uniform among provinces. The passenger cars are classified by tare weight, by the size of wheel balance or by the no. of cylinders. The trucks are classified by gross vehicle weight, by no. of axles and by no. of trailers. Buses are generally classified by weight. They are also classified by type of usage, i.e. school buses and municipal buses. The license fee is annual and based on the vehicle class.

The license fees reflect the inescapable road costs as well as costs of licensing. The object is to retrieve all or part of the inescapable costs i.e. capital costs and inescapable maintenance cost. The most important determinant factor of those costs is the axle weight. The roads are usually designed for a maximum axle weight as well as for the no. of impacts and climatic conditions.

On the basis of this, any license based on engine performance will lead to misallocation of resources. Licensing on the basis of vehicle weight is in the proper direction but it should be noted that a 2-axle, 10-ton truck requires much higher fixed assets than a 4-axle, 15-ton truck.

The classification in terms of passenger, truck and bus is an attempt to discriminate among different classes of users. But at this stage we are not in a position to compute the relative amount of discrimination among classes of users. We do not know if passenger vehicles contribute more or less than their share, and if they are discriminated in favour or against relative to the other vehicles.

<u>For-hire motor-carrier fees</u>

This class of fees is also known as public service fees. It applies only to the for-hire trucks (and buses) and as such it discriminates in favour of firms and individuals that own and operate their own vehicles. As such it discriminates in favour of the vertically integrated firms, one of the integral parts being provision of their own transportation, and therefore it leads to misallocation of resources. There is no economic rationale for making the road pricing a function of the type of ownership.

The for-hire transportation is regulated by the provincial and federal governments. The object of regulation is to set a certain level of services standards and to avoid excess capacity in the industry which occurred during the Depression years. It is appropriate to allocate the additional costs of regulation and licensing to the for-hire carriers. The present licensing fees might be substantially higher than the cost of regulation and licensing.

Other Fees

All other fees, i.e. operator's licenses, transfer of ownership, etc. may not be directly related with the stock or utilization of the road system. The level and structure of these fees should be similarly related to the appropriate costs.

V - THE SPECIFIC STATEMENT OF OBJECTIVES

We are now turning to the empirical side. We are faced with institutional, constitutional, and data constraints which introduce imperfections in the transportation market and impede the implementation of an optimal pricing mechanism.

Our intent would be to examine the roads on the basis of its economic markets in terms of goods carried such as passengers versus different freight classifications, in terms of geography and type of traffic, i.e. urban versus rural versus interurban. This intent may not be realistic, at least, within the scope of this paper. Constitutionally the road market belongs to the provinces and the road institutions were developed around the provincial authority to roads. Some distinction is being made in terms of urban versus rural and interurban roads but only on the basis of expenditure. The road revenue data is not classified on the same basis. Similarly no data exists with reference to the amount of road utilization in terms of vehicle-miles classified into urban, interurban and rural. Given these constraints and our basic objectives, the road system will be examined on the basis of the provincial market which may be disaggregated into other markets whenever possible.

There is a lack of specific data with respect to road utilization by each type of traffic such as passenger cars, buses, trucks of different sizes; nevertheless, it is plausible to develop satisfactory estimates.

Ideally, we would also like to allocate to each vehicle some amount of the road stock within the province that is being utilized by the same vehicle. In practice, this is impossible due to the fact that the vehicles are not limited to operate in specific regions; therefore, all the provincial stock will have to be allocated to all vehicles. I don't think this procedure would introduce any significant inequities.

The source of funds for the road stock are the provincial governments with contributions by the municipal and federal governments. The intention of this paper will be to price the whole of the road stock independently of its original funds and therefore we will ignore the source of funds.

One important issue is that with reference to the standards of quality and output in terms of construction and maintenance. The roads are designed on the basis of expected traffic of the thirtieth highest traffic volume hour. This is a rule of thumb for designing roads. The large part of the cost of design and construction of the roads is associated with the quality which improves safety,

speed and convenience. In spite of its importance, the question of optimality of the present quality standards will be left outside of the scope of this paper. It will be assumed that the standards are optimal as they stand although I would strongly recommend that this issue should be examined and analyzed in detail.

An issue associated with standards is that of social cost and more specifically, road congestion. The present amount of road capital stock is a function of the amount of utilization of the road during peak periods. The definition of road congestion is primarily handled by the road designers. The basic issue here is the fact that every vehicle operator utilizing a route during peak periods contributes to congestion and causes additional time delays to the rest of the vehicle operators. The hypothesis is that his presence during peak traffic periods causes social costs which are significantly higher than his own marginal costs of travelling during these peak traffic periods. In order, therefore, to allocate the existing resources efficiently, each road user should be faced not only with his own private costs but also with the additional social costs which he is responsible for. This leads to the question of peak load pricing which is a function of the cost of the road system and the additional social costs as well. It should be pointed out that the cost of the road system is not independent of the social cost of congestion since the amount of congestion is a partial determinant of the additions to capital stock.

In spite of their importance, the issues of standards, congestion and peak load pricing will not be examined in this paper. Congestion is a local issue in a much smaller framework than the provincial framework we are attempting to analyze. The issue of congestion and the associated one of peak load pricing has received a significant amount of attention in the literature in the last few years*. Specifically the Smeed Report ** is a practical attempt to apply the peak load pricing policies in the congested area of London, England and it has received wide publicity.*** I do not think I can add anything to the question of congestion at this stage.

This report will fill a gap in the existing literature which has devoted its attention mostly to the problems of congested areas. So far no analyses has been made to consider a pricing structure for the network as a whole.**** This will be our task: to develop a pricing mechanism for the network as a whole.

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* A.A. Walters, "The Theory and Measurement of Private and Social Costs of Highway Congestion", Econometrica, Vol. 29, No. 4, Oct. 1961.

** Road Pricing, The Economic and Technical Possibilities, Ministry of Transport, London, Her Majesty's Stationery Office, 1964 (Smeed Report).

*** Economist, 1971(January)

**** Road Pricing, Pg. 1

Vehicle pollution is an additional social cost. No attempt will be made on this paper to either attempt to quantify it or regulate it by pricing. I do not wish to underestimate the importance of this issue. Pollution is of significant social importance and should be examined in detail.

Similarly road accidents by vehicles contribute significantly to social costs. There are three types of costs due to accidents. These are composed of:

1. The police and regulation costs.
2. The costs due to road safety which is included in the road design and construction expenditures.
3. The costs due to the actual accidents. These may be reflected in the cost of insurance which is taken up by each individual on his own.

Hence, part of the cost of accidents is covered by the public through the road design and construction costs as well as the police and justice costs. The other part, the insurance costs burdens directly the individual road users. A high amount of road safety features will result in more costly design and construction of roads. This subsequently results in a lower number of traffic accidents which reflect in lower vehicle insurance costs. In this paper we are primarily interested in pricing the public road facilities therefore, only the first and second parts of the costs due to

accidents will be included. The third part, i.e. the insurance costs, is priced in the private market by the insurance companies. This pricing is assumed to be optimal.

The approach so far suggests that the roads should be examined within an industrial framework.*

The general objective of this paper is the efficient allocation of resources in transport. This objective may be met if each transportation mode covers its costs and a pricing mechanism is developed on the basis of cost escapability. In view of the limitations presented here, the realistic objective should be that of full cost recovery of the road system in each province. All road costs can be classified into escapable and inescapable on the basis of the vehicle-mile escapability of costs. Full cost recovery should take place through an efficient price mechanism where all inescapable operational costs are recovered through a periodic license fee. Further, periodic or licensing fees should not be based on the amount of utilization of the road, but on the engineering characteristics of the vehicle and road, and more specifically on the number of axles and the weight per axle, i.e. on the unit of axle-weight. This unit is the primary determinant in the highway design.** Similarly,

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* Prest has also used an industrial framework to examine the road system in England. A.R. Prest, "Some Aspects of Road Finance", p. 1.

** Highway cost allocation study, U.S. Congress.

the operation or utilization of roads charge should be based on the number of vehicle-miles as well as the weight per axle. More specifically, the unit for pricing should be the axle-miles-weight. It is the amount of weight per axle as well as the number of miles per axle that determines the amount of escapable costs. This pricing mechanism will result in minimum cross subsidization among different types of vehicles. The number of vehicles owned by each operator and the amount of vehicle-miles for each vehicle are a partial function of the licensing and vehicle-mile (fuel) charges. If the operator is faced with new fees that reflect the real costs, then it is expected that the operator will rationally alter his mix of vehicles and their utilization in the longer run as well as his tariff structure. As a result there will be an improvement in the allocation of resources in the economy.

Of course, full cost recovery of the road system could similarly take place* by varying the level of the present price structure. This might improve somehow the optimality between road and other modes, but may not alter at all the present cross-subsidization between different vehicle classes. This cross-subsidization will be avoided only by resorting to the pricing structure that was suggested above.

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* At this point assume inelastic demand for road services. This assumption will soon be relaxed.

There are additional issues associated with the transition from the present pricing structure to a new one. There are some costs associated with this transition in terms of the direct cost of educating bureaucrats and developing new charging methods and procedures. Another issue is that associated with the fact that the present system of charging is North America-wide. By introducing a new system which would be applied to a part of North America continent, i.e. Canada, or even a system that would only be applied to some provinces in Canada and not throughout Canada may cause additional costs with reference to the allocation of resources. These are difficult to estimate. An equally important issue is that associated with the economic proverb that "an old tax is a good tax". The present road pricing structure has been developed historically and is quite old. The present technology, and the economy in general, have allocated the resources given this present pricing mechanism. The introduction of a new pricing structure may upset the economic system and may redirect technology and business due to the introduction of a new set of incentives. The cost of this change may be quite substantial in terms of resources and should be considered although it is very difficult to estimate. All above points are very important; nevertheless, I believe we should proceed and attempt to evaluate and improve the present system in view of all the constraints.

The concept of full cost recovery should be further clarified at this stage. If the price of a good is below the optimum price it is not always possible to recover all costs. In Figure 23, all costs of producing q_1 units of output are (A+B). The supply curve SS is a long-run supply and includes all fixed and variable costs. The current price is p_1 and the optimum price is p_e. By increasing the price to its optimum level in the short-run, the costs (A+B) could not possibly be retrieved since, at the optimum price the quantity demanded would drop to q_e creating excess capacity of $(q_1 - q_2)$. The resulting revenue will be equal to (A) and not (A+B). If the demand is static we should base our decisions not on the long-run costs but rather on the short-run ones, because the optimum pricing would only create excess capacity. Only when the demand shifts to the right, i.e. when there is a growth in demand, it may be possible simultaneously to also increase the price until eventually it will reach the p_e level as shown in Figure 24. In this Figure, while demand was shifting the output remained constant at q_1 and prices were increased until they reached the optimum level p_e. At D'D' price was raised to Pl' and at D"D" price was raised to p_e. Subsequently any increase in demand would result in raising output i.e. at D'''D''' price is P_e and output is q_2. Hence, by full cost recovery, we mean maximum

FIG. 23

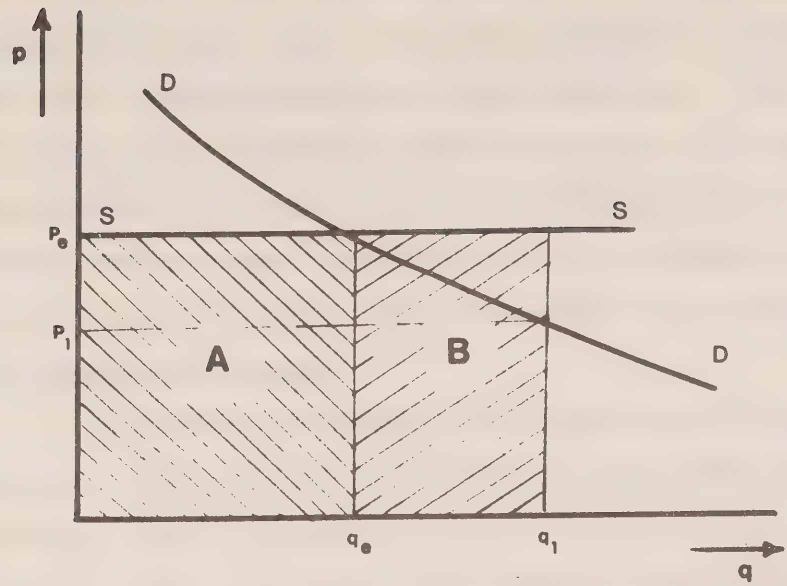
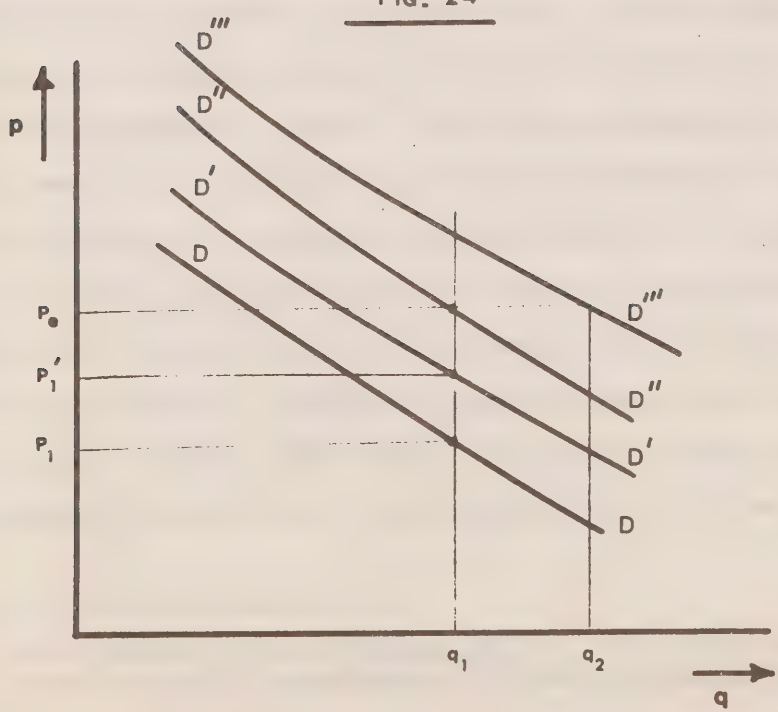


FIG. 24



retrievable costs without creating excess capacity. If the original price is under-optimal, no new investment should take place until the price reaches the optimum where all existing costs are being recovered. Only in the case of the inelastic demand curve are all costs immediately recoverable as shown in Figure 25. In this Figure the price may be increased to an optimum in the short tun and all costs are recoverable in the short tun.

The Empirical Approach

As shown previously, the introduction of the government function f(G) resultedin an unoptimal road pricing. This is shown in Figure 26. It will be assumed in this paper that the long-run supply function is horizontal and the cost of providing an additional service is constant in the long run. In other words the long run average costs are considered to be equal to the long run marginal costs.* Under this assumption, an estimate of the present gap between revenues and costs will indicate the amount of misallocation of resources in the roads. This is shown in Figure 27 on the assumption that the road system is subsidized,as will be shown later. In this Figure, C (Costs) is equal to oabf and R (Revenues) is equal to odcf. The Costs C are greater than the revenues R by abcd and the pricing at p_1 is below optimal.

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* A.R. Present "Road Financing", p. 227. Prest suggests this is in his examination of roads in England.

FIG. 25

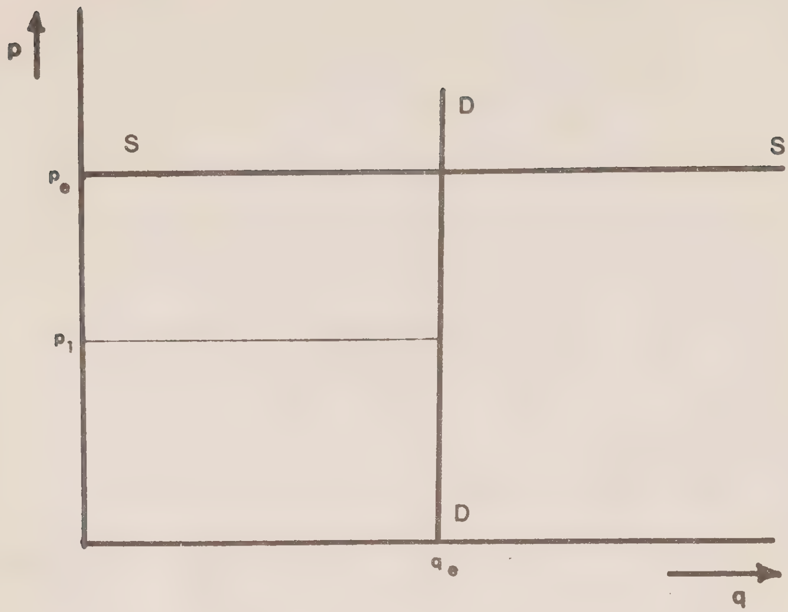


FIG. 26

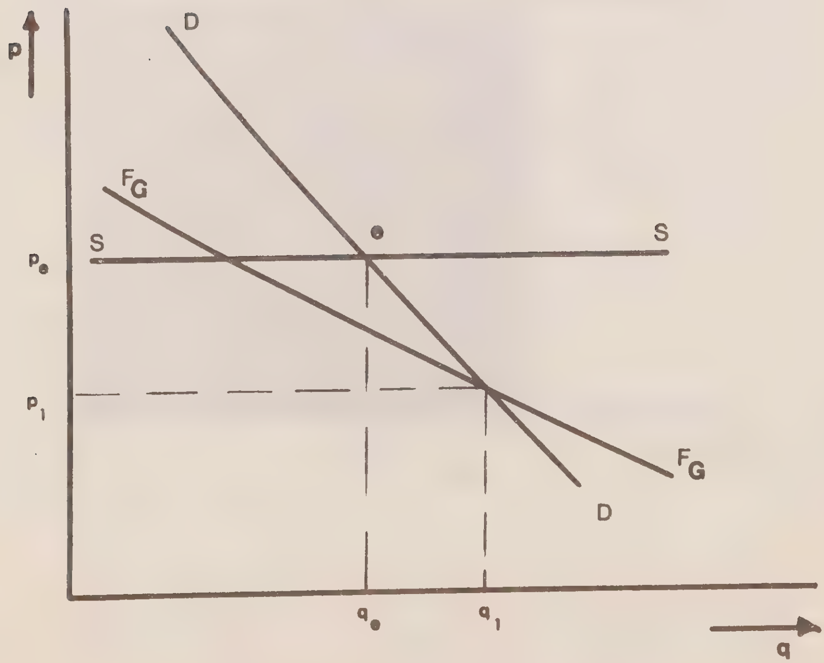
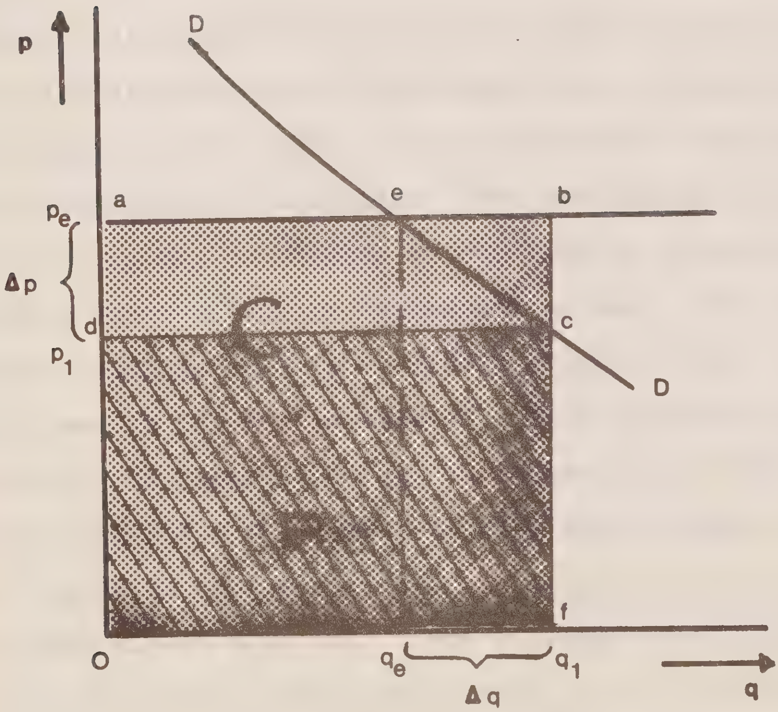


FIG. 27



The optimal situation will take place at the price p_e and the output q_e. This will be achieved by increasing the price by Δ p and decreasing the road output by Δ q. Given the horizontal supply curve, the Δ p is determined. The amount of Δ q will depend on the slope of the demand curve DD. Δ q is equal to zero if DD is inelastic. Due to the irreversibility characteristic of road investment, it is not possible to decrease output in the short-run. Any attempt to optimize the road industry in the short-run will result in excess capacity by an amount which is a function of the slope of the demand curve. The actual historical growth of the Canadian road transport system is an indication that this demand curve DD has been shifting to the right. It is assumed that this shift will continue to take place* The optimal price and output, therefore, may be reached by stalling or slowing down the road investment and by increasing prices. The amount of price increase will be inversely related to the degree of slowdown in road investment. This is shown in Figure 28 and 29. In Figure 28, road investment was stopped completely until the price and output reached the optimum at p_e and q_e. In Figure 29, investment was not stopped altogether but was slowed down and was followed by a gradual increase in prices from p_1 to p_2 to p_3 to p_4 to p_e, the differential

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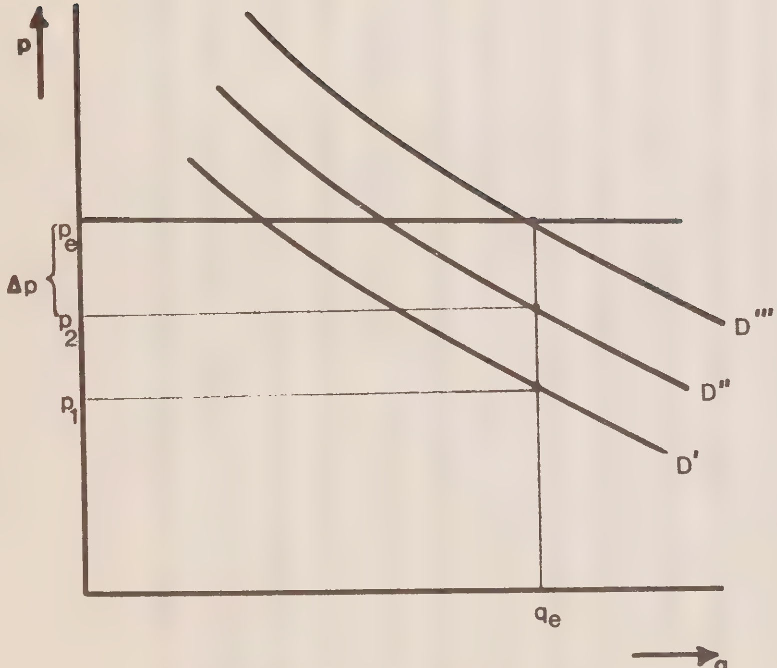
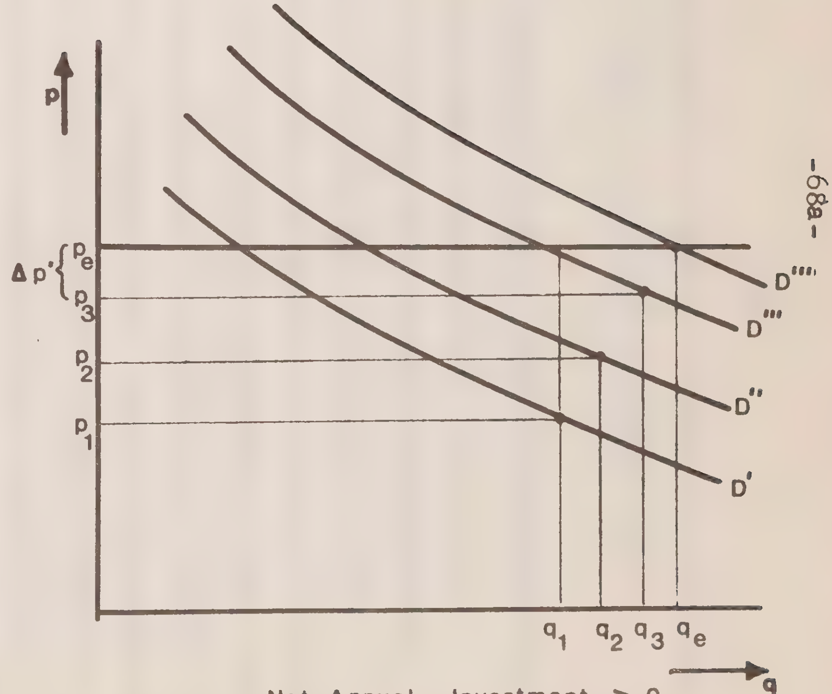
* Systems Research Group, <u>Transportation Projections Canada 2000</u>.

FIG. 28



Net Annual Investment = 0

FIG. 29



Net Annual Investment > 0

change in prices $\Delta p'$ in Figure 29 being less than the differential change in prices Δp in Figure 28.

The suggested approach requires abandonment of the present government function f(G) and the close coordination of pricing and supply of road services.

So far the roads were discussed in general. In the empirical analysis the market for roads will be disaggregated on the basis of cost escapability into a market for periodic road services (inescapable) and another one for operational (escapable) ones. Each of these markets will be further disaggregated by the type of vehicles. All road costs will be classified into escapable and inescapable; subsequently the inescapable costs will be allocated to different classes of vehicles and will be equally divided among vehicles in each class. The amount of present revenues can be estimated from each type of vehicle on the basis of the present pricing structure. If revenues are less than costs for a specific type of vehicle for a specific type of road service, then the amount of revenue deficiency may be computed, as well as the required change in pricing for cost recovery. This approach will be followed for all types of road services and for all types of vehicles. The cost of each service and the user will be identified. The present revenue will be estimated and the optimum price to cover all recoverable costs will

be computed. The first step in our empirical approach will be to classify and compute the revenues and costs. The development of a pricing structure will follow. These steps will take place in a subsequent paper.